ROYAL FREE LONDON NHS TRUST

ROYAL FREE HOSPITAL
HYBRID THEATRES EXTENSION

ENERGY STATEMENT

Client

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ABBREVIATIONS

RIBA	-	Royal Institute of British Architects
No.	-	Number
VAT	-	Value Added Tax
RHA	-	Regional Health Authority
mm	-	Millimetre
SO	-	Supervising Officer
HWS	-	Hot Water Services
CWS	-	Cold Water Service
LTHW	-	Low Temperature Hot Water
Kg	-	Kilogram
Sec	-	Second
KN	-	Kilonewton
sq.m	-	Square Metre
BS	-	British Standard
^{o}C	-	Degree Celsius
SWM	-	Softened Water Main
PVC	-	Poly Vinyl Chloride
BSP	-	British Standard Pipe Thread
Pa	-	Pascals
cu.m	-	Cubic Metres
Hr	-	Hour
V	-	Volts
A	-	Amps
kW	-	Kilowatt
Hz	-	Hertz
Ph	-	Phase
CIBSE	-	Chartered Institution of Building Services Engineers
IEE	-	Institution of Electrical Engineers
k or λ	-	Thermal conductivity

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Consulting Engineers

Energy Statement

Contents:

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1.0 Introduction:

XDA Consulting Ltd has been appointed by Royal Free London NHS Foundation Trust to undertake the BREEAM Assessment of the proposed New Hybrid Theatres. The design proposals are for a proposed extension to hospital at second and third storey level (above ground) with open undercroft area beneath (ground level) to deliver an extension to hybrid theatres alongside roof-level plant and enclosure and associated works.

This energy statement for the building follows the energy hierarchy:

1. Be lean: use less energy
2. Be clean: supply energy efficiently
3. Be green: use renewable energy

The following report demonstrates the feasibility of utilising LZC and renewable systems that may be suitable for the development.

The Energy Statement has been prepared by Dr Dianne Bowles, that has a PhD in Thermal Energy Storage and has been undertaking building performance modelling using IES Virtual Environment for 18 years. The author is an energy & sustainability consultant that undertakes thermal and energy modelling only, does not specify any products, and has no connection to any LZC technology or manufacturer.

2.0 Planning Policy

2.1 National Policy – The NPPF

The National Planning Policy Framework (NPPF), updated on December 2023, sets out the government's planning policies for England and how these are expected to be applied and states that:

The purpose of the planning system is to contribute to the achievement of sustainable development. At a very high level, the objective of sustainable development can be summarised as meeting the needs of the present without compromising the ability of future generations to meet their own needs.

Achieving sustainable development means that the planning system has three overarching objectives, which are interdependent and need to be pursued in mutually supportive ways:

Economic

Social

Environmental

So that sustainable development is pursued in a positive way, at the heart of the Framework is a presumption in favour of sustainable development.

2.2 Local Policy – Camden Local Plan

The Camden Local Plan, adopted in May 2017, sets out the Council's planning policies and replaces the Core Strategy and Development Policies planning documents. It ensures that Camden continues to have robust, effective and upto-date planning policies that respond to changing circumstances and the borough's unique characteristics and contribute to delivering the Camden Plan and other local priorities. The Local Plan will cover the period from 2016-2031.

Policy CC1 Climate change mitigation

The Council will require all development to minimise the effects of climate change and encourage all developments to meet the highest feasible environmental standards that are financially viable during construction and occupation.

We will:

a. promote zero carbon development and require all development to reduce carbon dioxide emissions through following the steps in the energy hierarchy;

b. require all major development to demonstrate how London Plan targets for carbon dioxide emissions have been met;

c. ensure that the location of development and mix of land uses minimise the need to travel by car and help to support decentralised energy networks;

d. support and encourage sensitive energy efficiency improvements to existing buildings;

e. require all proposals that involve substantial demolition to demonstrate that it is not possible to retain and improve the existing building; and

f. expect all developments to optimise resource efficiency.

For decentralised energy networks, we will promote decentralised energy by:

g. working with local organisations and developers to implement decentralised energy networks in the parts of Camden most likely to support them;

h. protecting existing decentralised energy networks (e.g. at Gower Street, Bloomsbury, King's Cross, Gospel Oak and Somers Town) and safeguarding potential network routes; and

i. requiring all major developments to assess the feasibility of connecting to an existing decentralised energy network, or where this is not possible establishing a new network.

To ensure that the Council can monitor the effectiveness of renewable and low carbon technologies, major developments will be required to install appropriate monitoring equipment.

3.0 Baseline Assessment – Building Regulations

In order to determine the baseline CO_2 emissions, a Part L 2021 compliance simulation was undertaken using NCM templates within the government approved VE compliance module of the IES software. A Target Emission Rate (TER) is generated from the dynamic simulation based upon a 'notional building', along with a breakdown of energy use for each system within the notional building. This TER forms the baseline against which the proposed development is compared.

The TER (baseline) for the scheme is 17.3 $kgCO_2/m^2$.

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4.0 Be Lean: Use Less Energy

The first step of the Energy Hierarchy methodology is to improve the design of the building fabric and services to maximise the energy efficiency and minimise the energy requirements. A visual of the 3D model from IES Virtual Environment is presented below.

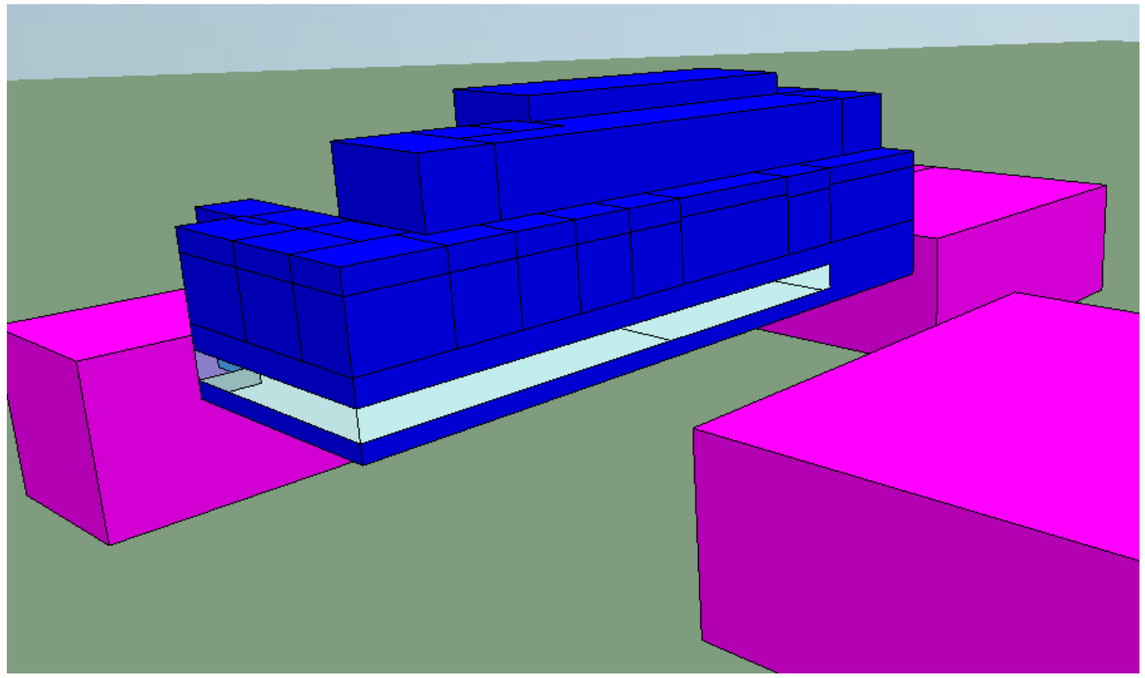

Figure 1 Visual of IES VE 3D model of new RFL Hybrid Theatres

4.1 Passive Design Measures

The design proposals for the building follows the basic 'fabric first' principles. The passive design analysis has considered the following.

Site location

The building is an extension to the Royal Free London Hospital in the Hampstead area of the London Borough of Camden. Therefore, the site location within the model is set to the nearest option: London Heathrow.

Site weather

The energy modelling has been undertaken using the required Part L compliance weather file: London_TRY.epw.

Microclimate

The extension is within a congested hospital site, surrounded by other buildings. Therefore surrounding buildings have been included in the model so any impacts on solar gain and wind speed around the proposed building can be taken account of.

Building Layout

The building layout is limited in terms of options due to the need to fit the building within an existing hospital site. The layout has been optimised to group together rooms requiring the same HVAC systems to reduce duct runs and limit heat loss/gain. The future office areas have been positioned to enable windows to be provided for natural daylight and views out, improving health & well-being for occupants.

Building Orientation

The building orientation is presented in Figure 2. The building has been orientated to enable the infill opportunity to be maximised in terms of functionality and ability to provide natural daylight to the future office spaces.

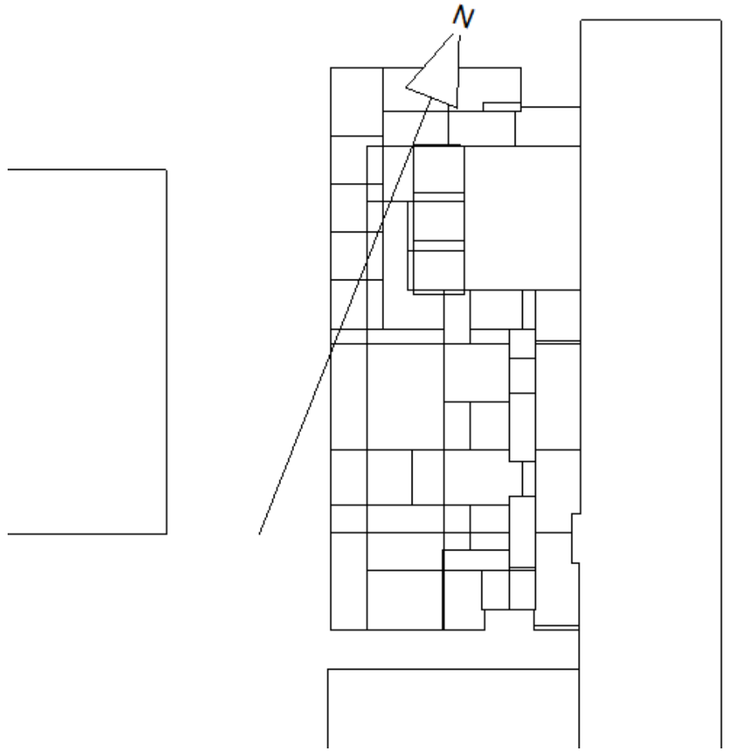

Figure 2 Orientation of new RFL Hybrid Theatres

Building Form

The building form has been considered based on limited space on site and with consideration to the form of construction. As this is a busy hospital site, the proposed form of construction of concrete floors and an SFS external wall system maximises the flexibility for the building layout and future adapatability.

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Building Fabric

The heat loss from the building has been reduced significantly by minimising the U-values which in turn shall minimise the energy consumption and CO_2 emissions associated with the heating.

The proposed U-values for the development are shown in Table 1 and are an average 39% improvement over the Part L (2021) limiting fabric parameters. The air tightness shall be improved to 1.0m^3hr/m^2 at 50Pa, improving on the Part L (2021) performance standards by 88%.

Building Element	U value W/m^2K	Building Regulations (AD L2A) limiting fabric parameters (W/m^2K)	% Improvement over Part L (2021)
Ground Floor	0.11	0.18	39%
External Walls	0.12	0.26	54%
Roof (flat)	0.11	0.18	39%
Windows & Glazed Doors (g-value 0.35 E/S/W g-value 0.5 N)	1.2	1.6	25%
Air Permeability $m^3/hr.m^2$ @ 50Pa	1.0	8.0	88%

Table 1 U-values of the Proposed Building Fabric

Thermal mass and other fabric storage

This is an infill development on an existing site, and cantilevers above an building and service yard. Thermal mass has been introduced in the form of concrete upper floors. This shall reduce the temperature fluctuations within the building as a result of external temperature changes and provide a more stable internal environment.

Building occupancy type

The proposed building is for operating theatres which requires closely controlled temperatures and ventilation rates to ensure air quality is maintained for infection control.

Daylighting Strategy

The future office spaces have been provided with windows to provide natural daylight and outlook. The electric lighting shall have dimmable daylight control.

Ventilation Strategy

Due to the use of the building, the internal environment needs to be closely controlled for infection control. Therefore all spaces are mechanically ventilated with fixed volume control. The ventilation will have heat recovery to reduce energy consumption and the specific fan power will be as low as is feasible to maintain the medical requirements.

Adaptation to climate change

The building is efficient in its form & fabric reducing its exposure to environmental conditions on a congested hospital site. The highly insulated fabric limits the heating requirements for the building and the limited opportunities for solar gain to the theatres due to the adjacent buildings limits any potential increase in solar gain during hotter weather periods.

All HVAC plant is located on the roof which shall enable future upgrades to plant to be possible.

Passive Design Analysis

The BRUKL output document from the Part L calculations confirms a 27% reduction in primary energy demand as a result of the passive design measures, as shown in

	Actual Building	Notional Building	Reduction %
Primary Energy Demand (kWh/m^2)	182.68	189.48	3.6%
Carbon Dioxide Emissions ($KgCO_2/m^2/yr$)	16.74	17.29	3.2%

Table 2 Reduction in energy demand & CO_2 emissions of the proposed scheme

4.2 Active Design Measures

The services strategy for the scheme has also been significantly improved over the baseline building to further reduce energy demand. These measures are outlined in Table 3.

System	Specification	
Heating	Air source heat pumps	SCoP 3.8 Variable speed pumps with differential sensor across pump
Cooling	Air source heat pumps + air cooled chillers	SEER 5.25
Heating & Cooling	Control Room AC – split system	SCoP 5.1 SEER 8.65
	Technical Rooms AC – split system	SCoP 4.01 SEER 6.42
Domestic hot water	Water source heat pumps (raising temperature from LTHW circuit)	SCoP 3.4 Pump type: Variable speed differential sensor across pump Secondary circulation: Circulation losses: 5W/m Loop length 100m 200w pump Time switch controlled

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System	Specification	
Ventilation	Fixed air volume	SFP 1.7 W/l/s 73.7% heat recovery
Lighting	130 lm/W throughout	
Lighting Controls	Circulation	Presence detection (auto on & dim)
	Stores Utility rooms TRX Room UPS Room	Presence detection (auto on-off)
	Theatres Recovery Bays Technical Rooms Control Room Anaesthetic	Manually on & dim

Table 3 Services Strategy

4.3 Be Lean Results

The Part L 2021 calculation has been re-run with the inclusion of the Lean design measures. The resulting Building Emission Rate is presented in Table 4. The results demonstrate that the passive and active design measures achieve 3% CO_2 reduction against the Baseline building.

	Carbon Dioxide Emissions ($KgCO_2/m^2/yr$)	Reduction from Baseline
Baseline	17.29	
Be Lean	16.74	3.2%

Table 4 Be Lean CO_2 emissions

5.0 Be Clean: Supply Energy Efficiently

Combined heat and power (CHP), also known as cogeneration, is the simultaneous generation of thermal and electrical energy from a single stream of fuel.

CHP installations can typically convert between 80% and 90% of the energy in the fuel into electrical power and useful heat. By generating the electricity in an on-site CHP unit, and utilizing the heat, electricity from conventional power stations is displaced and the substantial conversion, transmission and distribution losses are avoided. The resulting efficiency gives typical small-scale CHP installations a simple payback period of between 3 and 5 years, beyond which the units continue to save energy right up until the end of the life of the plant.

The capital cost of a small-scale CHP suitable for an extension of this project's nature is high compared to the equivalent boiler plant, and to make best use the unit should operate at close to full capacity for much of the year. This requires that both a constant electrical base load and heating load are present throughout the year. As this is an operating theatre, there will not be a constant large heat demand.

Therefore, CHP is not considered a viable option for the scheme.

District heating has been considered on the scheme. The main hospital heating system includes gas fired boilers installed in the 2000's, cooling system via water cooled water chillers and the existing domestic hot water are calorifiers fed from the gas fired boilers. Due to the age of the existing gas fired boilers, the system efficiency is likely to be circa 70%. However, the existing heating distribution is via Steam at 8barG, reducing to 1.7barG at satellite plant rooms, so with distribution losses, blow downs, loss of condensate return, etc. the overall system efficiency is likely to be less than 70%. Initial Part L calculations confirmed the building would fail to meet Building Regulations Part L if connected to the district heating system. The NHS also have Net Zero directives promoting the phasing out of fossil fuel heating plant in favour of electric heat pumps, so it is likely that the existing Steam system will be replaced with a water based network in the foreseeable future. Therefore, connection to the existing hospital Steam district heating is not a viable solution.

6.0 Be Green: Use Renewable Energy

When considering LZC technologies available, the overall servicing strategy for the building has been considered together with an analysis of the site and surrounding buildings.

The measures in place to make the building lean have provided good levels of energy and CO_2 reduction. To improve the energy performance of the building it is necessary to establish which LZC technologies are feasible.

As this is an NHS scheme, it is potentially eligible for The Public Sector Decarbonisation Scheme. The scheme provides grants for public sector bodies to fund heat decarbonisation and energy efficiency measures. In February 2024, the Department for Energy Security and Net Zero (DESNZ) confirmed Phase 4 of the Public Sector Decarbonisation Scheme (PSDS), to be delivered by Salix Finance. Further details can be found at: https://www.salixfinance.co.uk/greater-emphasis-carbon-savings-new-phase-public-sector-decarbonisation-scheme

It should be noted, as part of the lean strategy air source heat pumps (a low carbon technology) have been included to achieve Part L 2021 compliance. The remaining LZC technologies have been reviewed to determine if there is a more suitable technology than air source heats pumps and/or a combination of technologies to provide further CO_2 reductions.

Below is an overview of these LZC technologies.

Solar Hot Water: Solar hot water heating is a technology that is proven to be reliable, cost effective and provide low to medium CO_2 savings. Panels are positioned on roofs and use the suns energy to provide domestic hot water. Panels provide an optimum performance when mounted facing due south and inclined at an angle of 30-40˚. During periods where the solar intensity is not high enough to provide the required amount of domestic hot water, the LTHW heating system will provide the shortfall. Systems which use larger volume cylinders to store the hot water operate more efficiently, as this allows for more solar hot water to be generated during periods of low domestic hot water use.

As the new Hybrid Theatres do not have a particularly significant hot water demand, only hand washing, this technology is not considered appropriate.

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Photovoltaics: Solar photovoltaic (PV) technology is a semi-conductor based technology that converts the energy in sunlight into electricity. Monocrystalline PV systems are considered to be the most appropriate, as they are the most cost effective. The use of PV systems on this scheme would be practical given the area of roof that is not shaded throughout the year. The optimum incline and orientation for maximum performance is 30 degrees incline from the horizontal facing south. PV arrays will interface with the LV distribution system and an export facility to the grid will be established.

The viable quantity of PV the scheme can provide is presented in Table 5 along with the electricity generated and CO_2 reductions that could be achieved.

Quantity of PV kWp	Electricity Generated kWh/yr	CO_2 Reduction $kgCO_2/yr$	Capital Cost (based on £1,132/kW[1])	Saving £/yr (based on 17.74p/kWh[2])	Payback years
50	33,663	4,268	£56,600	£5,972	9.5

Table 5 PV energy, CO_2 and payback analysis

Providing 50kWp (~250m²)of PV could generate 33,663 kWh/yr of electricity reducing CO_2 emissions by over 4,268 $kgCO_2/yr$. The only equipment required in the plant room would be an inverter.

Please note – the number of PV panels provided could be increased and/or decreased dependent upon the output of PV panel selected and panel efficiency.

The PV quantity provided shall provide between 5-10% of the buildings electricity demand, depending on the time of year. There shall not be an excess to export to the grid so there is no financial incentive to do this. It would be most cost efficient to use all electricity generated in the building to reduce annual electricity costs.

Provision for battery storage for excess PV is not appropriate for this building as there will be no excess.

There are no longer any feed-in tariffs for PV.

Wind Turbines: The site is not considered suitable for wind due to the dense urban location.

Biomass Boilers: Biomass boilers use either wood chips or wood pellets as the fuel. The use of biomass as an energy source has become more widespread in recent years. Biomass offers CO_2 saving, with a high reliability of plant. Though biomass plant is more expensive than gas fired plant, it has the potential to provide the majority of the heating load almost CO_2 free.

Storage and delivery of biomass fuel must be carefully considered to ensure that sufficient fuel is available all year round and the site is accessible to delivery vehicles even in the depths of winter.

Whilst biomass boilers provide a low carbon solution, biomass boilers are much less efficient than alternatives, requiring greater quantities of fuel to meet the required output. Furthermore, although biomass is carbon neutral because it has absorbed all the carbon it is releasing, the carbon release is intensive and increases air quality issues.

Furthermore the pollution associated with deliveries of the biomass should also be taken into account.

Given the storage requirements and air quality impacts of a biomass system, this has been discounted from consideration for the scheme.

Ground Source Heat Pumps: Ground source heat pumps use the earth as a thermal sink and provide a source of cooling as well as heating. Ground source heat pumps use either vertical bore holes or horizontal pipework systems as the source of heating and cooling and have extremely good efficiencies, generally converting 1kW of electrical energy into 5-6 kW of heating and cooling. These efficiencies mean that ground source heat pumps provide a medium CO2 benefit.

The site is significantly congested with many buildings in close proximity, therefore there is little available land for boreholes. Given the site constraints and the capital costs associated with this technology are higher due to the boreholes, this technology it has been discounted.

Air Source Heat Pumps: Air source heat pumps operate in a similar manner to ground source heat pumps, but use ambient air as the heat sink. Air source heat pumps are much cheaper than ground source, though provide lower operating efficiencies.

Air source heat pumps are a viable technology for the scheme and have been specified as the base technology in the scheme to achieve Building Regulations compliance. The other LZC technologies are being compared against the ASHPs to determine if the ASHPs and/or an alternative technology would be the most appropriate for the site.

Air source heat pumps have been included within the 'baseline' building to enable Part L compliance to be achieved. Therefore the energy generation and CO_2 savings have not been assessed,

Small Scale Hydro Power: Not suitable for this site due to the lack of available water source.

Tidal Power: Not suitable for this site due to the lack of available water source.

Wave Power: Not suitable for this site due to the lack of available water source

6.1 Be Green Results

As the alternative technologies for heating and domestic hot water are more costly and technically challenging than the air source heat pumps originally selected, air source heat pumps remain the most viable technology.

A summary of the most viable low and zero carbon technologies are presented in Table 6 with the energy reduction that will be achieved and the CO_2 reduction.

System	Size	Energy Reduction kWh/yr	CO_2 Reduction $kgCO_2/yr$
Air Source Heat Pumps	Already within the baseline building therefore not included within this analysis		
Photovoltaics	50 kWp	33,663	4,268

Table 6 Viable LZC technologies with energy & CO_2 reductions

Therefore it can be concluded the PV is the most appropriate technology for the scheme. The Part L 2021 calculations have been re-run with the inclusion of 50kWp of PV panels. The results are shown in Table 7 and demonstrate the inclusion of PV on the scheme will reduce the CO_2 emissions from the Lean building by over 19%.

1 https://www.gov.uk/government/statistics/solar-pv-cost-data

2 https://www.gov.uk/government/statistical-data-sets/gas-and-electricity-prices-in-the-non-domestic-sector

	Carbon Dioxide Emissions ($KgCO_2/m^2/yr$)	Reduction from Baseline
Be Lean	16.74	
Be Green	13.54	19.1%

Table 7 Be Green CO_2 emissions

The sizing of the air source heat pumps shall enable only the heat demand for this building to be met. The PV array is sized to meet some, not all, of the electrical demand for the Hybrid Theatres. There is not the opportunity to export heat or power to other areas of the hospital.

7.0 Results

As discussed in the previous section, the most viable LZC technology for the scheme is PV (as ASHP already included in the baseline building). The CO_2 reductions for each stage of the energy hierarchy are summarised in Table 8 and demonstrate that an overall 21.7% reduction in CO_2 emissions can be achieved due to the Lean and Green options adopted in the scheme.

	Carbon Dioxide Emissions ($KgCO_2/m^2/yr$)	CO_2 savings at each stage		Reduction from Baseline %
		($KgCO_2/m^2/yr$)	%	
Baseline	17.29			
Be Lean	16.74	0.55	3.2%	3.2%
Be Green	13.54	3.2	19.1%	21.7%

Table 8 Energy Hierarchy Results

8.0 Conclusion

The energy statement has determined that the scheme has been developed with a ‘fabric first’ approach that has resulted in almost 4% reduction in the heating and cooling demand for the scheme.

The passive and active design measures adopted for the scheme, including air source heat pumps, result in a Lean building that achieves over 3% CO_2 reduction over the baseline building.

It was determined 50kWp of photovoltaic panels will enable the proposed scheme to further reduce the CO_2 emissions by 19.1%.

Overall, the proposed Royal Free London New Hybrid Theatres achieves a carbon reduction of 21.7% over a Part L 2021 compliant building.

Therefore the requirement of the Camden Local Plan Planning Policy CC1 Climate change mitigation has been met.

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Building Services
Consulting Engineers

9.0 Appendix – Lean & Green BRUKL reports

Link to Contents

BRUKL Output Document

HM Government

Compliance with England Building Regulations Part L 2021

Project name

RFL Hybrid Theatre LEAN

As designed

Date: Tue Oct 01 09:45:24 2024

Administrative information

Building Details

Address: Royal Free Hospital , London, Postcode

Certifier details

Name: XDA Consulting Ltd

Telephone number: Phone

Address: Street Address, City, Postcode

Certification tool

Calculation engine: Apache

Calculation engine version: 7.0.26

Interface to calculation engine: IES Virtual Environment

Interface to calculation engine version: 7.0.26

BRUKL compliance module version: v6.1.e.1

Foundation area [m²]: 667.56

The CO_2 emission and primary energy rates of the building must not exceed the targets

Target CO_2 emission rate (TER), $kgCO_2/m^2$annum	17.29	
Building CO_2 emission rate (BER), $kgCO_2/m^2$annum	16.74	
Target primary energy rate (TPER), kWh_{PE}/m^2annum	189.48	
Building primary energy rate (BPER), kWh_{PE}/m^2annum	182.68	
Do the building's emission and primary energy rates exceed the targets?	BER =< TER	BPER =< TPER

The performance of the building fabric and fixed building services should achieve reasonable overall standards of energy efficiency

Fabric element	$U_{a\text{-}Limit}$	$U_{a\text{-}Calc}$	$U_{i\text{-}Calc}$	First surface with maximum value
Walls*	0.26	0.12	0.12	L0000000:Surf[0]
Floors	0.18	0.13	0.13	L0000004:Surf[0]
Pitched roofs	0.16	-	-	No pitched roofs in building
Flat roofs	0.18	0.11	0.11	L0000000:Surf[12]
Windows** and roof windows	1.6	1.22	1.22	L0000000:Surf[6]
Rooflights***	2.2	-	-	No roof lights in building
Personnel doors^	1.6	-	-	No personnel doors in building
Vehicle access & similar large doors	1.3	-	-	No vehicle access doors in building
High usage entrance doors	3	-	-	No high usage entrance doors in building

$U_{a\text{-}Limit}$ = Limiting area-weighted average U-values [W/(m²K)] $U_{i\text{-}Calc}$ = Calculated maximum individual element U-values [W/(m²K)]

$U_{a\text{-}Calc}$ = Calculated area-weighted average U-values [W/(m²K)]

* Automatic U-value check by the tool does not apply to curtain walls whose limiting standard is similar to that for windows.

** Display windows and similar glazing are excluded from the U-value check. *** Values for rooflights refer to the horizontal position.

^ For fire doors, limiting U-value is 1.8 W/m²K

NB: Neither roof ventilators (inc. smoke vents) nor swimming pool basins are modelled or checked against the limiting standards by the tool.

Air permeability	Limiting standard	This building
$m^3/(h.m^2)$ at 50 Pa	8	1

Building services

For details on the standard values listed below, system-specific guidance, and additional regulatory requirements, refer to the Approved Documents.

Whole building lighting automatic monitoring & targeting with alarms for out-of-range values	NO
Whole building electric power factor achieved by power factor correction	>0.95

1- ASHP & air cooled chillers

	Heating efficiency	Cooling efficiency	Radiant efficiency	SFP [W/(l/s)]	HR efficiency
This system	2.57	5.25	0	1.7	0.74
Standard value	2.5*	4.5**	N/A	2^	N/A
Automatic monitoring & targeting with alarms for out-of-range values for this HVAC system					YES

* Standard shown is for all types >12 kW output, except absorption and gas engine heat pumps.

** Standard shown is for air-cooled chillers >=400 kW. For chillers <400 kW, limiting SEER is 4.

^ Limiting SFP may be increased by the amounts specified in the Approved Documents if the installation includes particular components.

2- Theatre 17 Technical AC

	Heating efficiency	Cooling efficiency	Radiant efficiency	SFP [W/(l/s)]	HR efficiency
This system	3.2	6.42	0	-	-
Standard value	2.5*	5	N/A	N/A	N/A
Automatic monitoring & targeting with alarms for out-of-range values for this HVAC system					YES

* Standard shown is for all types >12 kW output, except absorption and gas engine heat pumps.

3- Control AC

	Heating efficiency	Cooling efficiency	Radiant efficiency	SFP [W/(l/s)]	HR efficiency
This system	4.04	8.65	0	-	-
Standard value	2.5*	5	N/A	N/A	N/A
Automatic monitoring & targeting with alarms for out-of-range values for this HVAC system					YES

* Standard shown is for all types >12 kW output, except absorption and gas engine heat pumps.

4- Theatre 18 Technical AC

	Heating efficiency	Cooling efficiency	Radiant efficiency	SFP [W/(l/s)]	HR efficiency
This system	3.2	6.42	0	-	-
Standard value	2.5*	5	N/A	N/A	N/A
Automatic monitoring & targeting with alarms for out-of-range values for this HVAC system					YES

* Standard shown is for all types >12 kW output, except absorption and gas engine heat pumps.

"No HWS in project, or hot water is provided by HVAC system"

Zone-level mechanical ventilation, exhaust, and terminal units

ID	System type in the Approved Documents
A	Local supply or extract ventilation units
B	Zonal supply system where the fan is remote from the zone
C	Zonal extract system where the fan is remote from the zone
D	Zonal balanced supply and extract ventilation system
E	Local balanced supply and extract ventilation units
F	Other local ventilation units
G	Fan assisted terminal variable air volume units
H	Fan coil units
I	Kitchen extract with the fan remote from the zone and a grease filter

NB: Limiting SFP may be increased by the amounts specified in the Approved Documents if the installation includes particular components.

Zone name	SFP [W/(l/s)]									HR efficiency	
ID of system type	A	B	C	D	E	F	G	H	I		
Standard value	0.3	1.1	0.5	2.3	2	0.5	0.5	0.4	1	Zone	Standard
L03 Theatre 17 Technical	-	-	-	1.8	-	-	-	-	-	-	N/A
L03 Control Room	-	-	-	1.8	-	-	-	-	-	-	N/A
L03 Theatre 18 Technical	-	-	-	1.8	-	-	-	-	-	-	N/A

General lighting and display lighting	General luminaire	Display light source	
Zone name	Efficacy [lm/W]	Efficacy [lm/W]	Power density [W/m²]
Standard value	95	80	0.3
L02	130	-	-
L03 Lobby	130	-	-
L03 Clean Utility	130	-	-
L03 Dirty Utility	130	-	-
L03 Lobby	130	-	-
L03 Lobby	130	-	-
L03 Linen Store	130	-	-
L03 Anaesthetic (Theatre 17)	130	-	-
L03 Theatre 17 Technical	130	-	-
L03 Theatre 17	130	-	-
L03 Consumables Store	130	-	-
L03 Control Room	130	-	-
L03 Theatre Store	130	-	-
L03 Corridor	130	-	-
L03 Exit Bay	130	-	-
L03 Lobby	130	-	-
L03 Theatre 18	130	-	-
L03 Corridor	130	-	-
L03 Theatre 18 Technical	130	-	-
L03 Anaesthetic (Theatre 18)	130	-	-
L03 Bay 1	130	-	-
L03 Bay 2	130	-	-
L03 Bay 3	130	-	-
L03 Bay 4	130	-	-
L03 Staff Base	130	-	-
L03 Bay 6	130	-	-
L03 Bay 5	130	-	-
L03 Lobby	130	-	-
L03 Recovery Bays	130	-	-

The spaces in the building should have appropriate passive control measures to limit solar gains in summer

Zone	Solar gain limit exceeded? (%)	Internal blinds used?
L02	NO (-58.6%)	NO
L03 Lobby	N/A	N/A
L03 Clean Utility	N/A	N/A

Zone	Solar gain limit exceeded? (%)	Internal blinds used?
L03 Dirty Utility	N/A	N/A
L03 Lobby	N/A	N/A
L03 Lobby	N/A	N/A
L03 Linen Store	N/A	N/A
L03 Anaesthetic (Theatre 17)	N/A	N/A
L03 Theatre 17 Technical	N/A	N/A
L03 Theatre 17	N/A	N/A
L03 Consumables Store	N/A	N/A
L03 Control Room	N/A	N/A
L03 Theatre Store	N/A	N/A
L03 Corridor	N/A	N/A
L03 Exit Bay	N/A	N/A
L03 Lobby	N/A	N/A
L03 Theatre 18	N/A	N/A
L03 Corridor	N/A	N/A
L03 Theatre 18 Technical	N/A	N/A
L03 Anaesthetic (Theatre 18)	N/A	N/A
L03 Bay 1	N/A	N/A
L03 Bay 2	N/A	N/A
L03 Bay 3	N/A	N/A
L03 Bay 4	N/A	N/A
L03 Staff Base	N/A	N/A
L03 Bay 6	N/A	N/A
L03 Bay 5	N/A	N/A
L03 Lobby	N/A	N/A
L03 Recovery Bays	N/A	N/A

Regulation 25A: Consideration of high efficiency alternative energy systems

Were alternative energy systems considered and analysed as part of the design process?	YES
Is evidence of such assessment available as a separate submission?	YES
Are any such measures included in the proposed design?	YES

Technical Data Sheet (Actual vs. Notional Building)

Building Global Parameters

	Actual	Notional
Floor area [m^2]	1335.1	1335.1
External area [m^2]	2184.9	2184.9
Weather	LON	LON
Infiltration [m^3/hm^2@ 50Pa]	1	3
Average conductance [W/K]	352.89	767.17
Average U-value [W/m^2K]	0.16	0.35
Alpha value* [%]	27.03	10

* Percentage of the building's average heat transfer coefficient which is due to thermal bridging

Building Use

% Area	Building Type
	Retail/Financial and Professional Services
	Restaurants and Cafes/Drinking Establishments/Takeaways
	Offices and Workshop Businesses
	General Industrial and Special Industrial Groups
	Storage or Distribution
	Hotels
100	**Residential Institutions: Hospitals and Care Homes**
	Residential Institutions: Residential Schools
	Residential Institutions: Universities and Colleges
	Secure Residential Institutions
	Residential Spaces
	Non-residential Institutions: Community/Day Centre
	Non-residential Institutions: Libraries, Museums, and Galleries
	Non-residential Institutions: Education
	Non-residential Institutions: Primary Health Care Building
	Non-residential Institutions: Crown and County Courts
	General Assembly and Leisure, Night Clubs, and Theatres
	Others: Passenger Terminals
	Others: Emergency Services
	Others: Miscellaneous 24hr Activities
	Others: Car Parks 24 hrs
	Others: Stand Alone Utility Block

Energy Consumption by End Use [kWh/m^2]

	Actual	Notional
Heating	3.84	2.54
Cooling	3.97	10.36
Auxiliary	95.71	93.44
Lighting	16.47	16.39
Hot water	3.91	6.05
Equipment*	166.15	166.15
TOTAL**	**123.9**	**128.78**

* Energy used by equipment does not count towards the total for consumption or calculating emissions.
** Total is net of any electrical energy displaced by CHP generators, if applicable.

Energy Production by Technology [kWh/m^2]

	Actual	Notional
Photovoltaic systems	0	0
Wind turbines	0	0
CHP generators	0	0
Solar thermal systems	0	0
Displaced electricity	*0*	*0*

Energy & CO_2 Emissions Summary

	Actual	Notional
Heating + cooling demand [MJ/m^2]	136.61	131.43
Primary energy [kWh_{PE}/m^2]	182.68	189.48
Total emissions [kg/m^2]	16.74	17.29

HVAC Systems Performance

System Type		Heat dem MJ/m2	Cool dem MJ/m2	Heat con kWh/m2	Cool con kWh/m2	Aux con kWh/m2	Heat SSEEF	Cool SSEER	Heat gen SEFF	Cool gen SEER
[ST] Constant volume system (variable fresh air rate), [HS] ASHP, [HFT] Electricity, [CFT] Electricity										
	Actual	7.9	76.2	0.6	4	89	3.8	5.25	2.57	5.25
	Notional	26.4	108.1	2.6	10.6	91.6	2.78	2.84	----	----
[ST] Split or multi-split system, [HS] ASHP, [HFT] Electricity, [CFT] Electricity										
	Actual	1492.1	44	103.4	2.5	241.5	4.01	4.8	3.2	6.42
	Notional	0	52.6	0	5.1	120.8	2.78	2.84	----	----
[ST] Split or multi-split system, [HS] ASHP, [HFT] Electricity, [CFT] Electricity										
	Actual	1567.7	41.4	85.4	1.8	241.5	5.1	6.46	4.04	8.65
	Notional	0	45.5	0	4.4	120.8	2.78	2.84	----	----
[ST] Split or multi-split system, [HS] ASHP, [HFT] Electricity, [CFT] Electricity										
	Actual	1477.6	45.7	102.4	2.6	241.5	4.01	4.8	3.2	6.42
	Notional	0	54.4	0	5.3	120.8	2.78	2.84	----	----

Key to terms

Heat dem [MJ/m2]	= Heating energy demand
Cool dem [MJ/m2]	= Cooling energy demand
Heat con [kWh/m2]	= Heating energy consumption
Cool con [kWh/m2]	= Cooling energy consumption
Aux con [kWh/m2]	= Auxiliary energy consumption
Heat SSEFF	= Heating system seasonal efficiency (for notional building, value depends on activity glazing class)
Cool SSEER	= Cooling system seasonal energy efficiency ratio
Heat gen SSEFF	= Heating generator seasonal efficiency
Cool gen SSEER	= Cooling generator seasonal energy efficiency ratio
ST	= System type
HS	= Heat source
HFT	= Heating fuel type
CFT	= Cooling fuel type

BRUKL Output Document

HM Government

Compliance with England Building Regulations Part L 2021

Project name

RFL Hybrid Theatre GREEN

As designed

Date: Tue Oct 01 11:26:46 2024

Administrative information

Building Details

Address: Royal Free Hospital , London, Postcode

Certifier details

Name: XDA Consulting Ltd

Telephone number: Phone

Address: Street Address, City, Postcode

Certification tool

Calculation engine: Apache

Calculation engine version: 7.0.26

Interface to calculation engine: IES Virtual Environment

Interface to calculation engine version: 7.0.26

BRUKL compliance module version: v6.1.e.1

Foundation area [m²]: 667.56

The CO_2 emission and primary energy rates of the building must not exceed the targets

Target CO_2 emission rate (TER), $kgCO_2/m^2.annum$	17.29	
Building CO_2 emission rate (BER), $kgCO_2/m^2.annum$	15.64	
Target primary energy rate (TPER), $kWh_{PE}/m^2.annum$	189.48	
Building primary energy rate (BPER), $kWh_{PE}/m^2.annum$	169.96	
Do the building's emission and primary energy rates exceed the targets?	BER =< TER	BPER =< TPER

The performance of the building fabric and fixed building services should achieve reasonable overall standards of energy efficiency

Fabric element	$U_{a\text{-}Limit}$	$U_{a\text{-}Calc}$	$U_{i\text{-}Calc}$	First surface with maximum value
Walls*	0.26	0.12	0.12	L0000000:Surf[0]
Floors	0.18	0.13	0.13	L0000004:Surf[0]
Pitched roofs	0.16	-	-	No pitched roofs in building
Flat roofs	0.18	0.11	0.11	L0000000:Surf[12]
Windows** and roof windows	1.6	1.22	1.22	L0000000:Surf[6]
Rooflights***	2.2	-	-	No roof lights in building
Personnel doors^	1.6	-	-	No personnel doors in building
Vehicle access & similar large doors	1.3	-	-	No vehicle access doors in building
High usage entrance doors	3	-	-	No high usage entrance doors in building

$U_{a\text{-}Limit}$ = Limiting area-weighted average U-values [W/(m²K)] $U_{i\text{-}Calc}$ = Calculated maximum individual element U-values [W/(m²K)]

$U_{a\text{-}Calc}$ = Calculated area-weighted average U-values [W/(m²K)]

* Automatic U-value check by the tool does not apply to curtain walls whose limiting standard is similar to that for windows.

** Display windows and similar glazing are excluded from the U-value check. *** Values for rooflights refer to the horizontal position.

^ For fire doors, limiting U-value is 1.8 W/m²K

NB: Neither roof ventilators (inc. smoke vents) nor swimming pool basins are modelled or checked against the limiting standards by the tool.

Air permeability	Limiting standard	This building
$m^3/(h.m^2)$ at 50 Pa	8	1

Building services

For details on the standard values listed below, system-specific guidance, and additional regulatory requirements, refer to the Approved Documents.

Whole building lighting automatic monitoring & targeting with alarms for out-of-range values	NO
Whole building electric power factor achieved by power factor correction	>0.95

1- ASHP & air cooled chillers

	Heating efficiency	Cooling efficiency	Radiant efficiency	SFP [W/(l/s)]	HR efficiency
This system	2.57	5.25	0	1.7	0.74
Standard value	2.5*	4.5**	N/A	2^	N/A
Automatic monitoring & targeting with alarms for out-of-range values for this HVAC system					YES

* Standard shown is for all types >12 kW output, except absorption and gas engine heat pumps.

** Standard shown is for air-cooled chillers >=400 kW. For chillers <400 kW, limiting SEER is 4.

^ Limiting SFP may be increased by the amounts specified in the Approved Documents if the installation includes particular components.

2- Theatre 17 Technical AC

	Heating efficiency	Cooling efficiency	Radiant efficiency	SFP [W/(l/s)]	HR efficiency
This system	3.2	6.42	0	-	-
Standard value	2.5*	5	N/A	N/A	N/A
Automatic monitoring & targeting with alarms for out-of-range values for this HVAC system					YES

* Standard shown is for all types >12 kW output, except absorption and gas engine heat pumps.

3- Control AC

	Heating efficiency	Cooling efficiency	Radiant efficiency	SFP [W/(l/s)]	HR efficiency
This system	4.04	8.65	0	-	-
Standard value	2.5*	5	N/A	N/A	N/A
Automatic monitoring & targeting with alarms for out-of-range values for this HVAC system					YES

* Standard shown is for all types >12 kW output, except absorption and gas engine heat pumps.

4- Theatre 18 Technical AC

	Heating efficiency	Cooling efficiency	Radiant efficiency	SFP [W/(l/s)]	HR efficiency
This system	3.2	6.42	0	-	-
Standard value	2.5*	5	N/A	N/A	N/A
Automatic monitoring & targeting with alarms for out-of-range values for this HVAC system					YES

* Standard shown is for all types >12 kW output, except absorption and gas engine heat pumps.

"No HWS in project, or hot water is provided by HVAC system"

Zone-level mechanical ventilation, exhaust, and terminal units

ID	System type in the Approved Documents
A	Local supply or extract ventilation units
B	Zonal supply system where the fan is remote from the zone
C	Zonal extract system where the fan is remote from the zone
D	Zonal balanced supply and extract ventilation system
E	Local balanced supply and extract ventilation units
F	Other local ventilation units
G	Fan assisted terminal variable air volume units
H	Fan coil units
I	Kitchen extract with the fan remote from the zone and a grease filter

NB: Limiting SFP may be increased by the amounts specified in the Approved Documents if the installation includes particular components.

Zone name	SFP [W/(l/s)]									HR efficiency	
ID of system type	A	B	C	D	E	F	G	H	I		
Standard value	0.3	1.1	0.5	2.3	2	0.5	0.5	0.4	1	Zone	Standard
L03 Theatre 17 Technical	-	-	-	1.8	-	-	-	-	-	-	N/A
L03 Control Room	-	-	-	1.8	-	-	-	-	-	-	N/A
L03 Theatre 18 Technical	-	-	-	1.8	-	-	-	-	-	-	N/A

General lighting and display lighting	General luminaire	Display light source	
Zone name	Efficacy [lm/W]	Efficacy [lm/W]	Power density [W/m²]
Standard value	95	80	0.3
L02	130	-	-
L03 Lobby	130	-	-
L03 Clean Utility	130	-	-
L03 Dirty Utility	130	-	-
L03 Lobby	130	-	-
L03 Lobby	130	-	-
L03 Linen Store	130	-	-
L03 Anaesthetic (Theatre 17)	130	-	-
L03 Theatre 17 Technical	130	-	-
L03 Theatre 17	130	-	-
L03 Consumables Store	130	-	-
L03 Control Room	130	-	-
L03 Theatre Store	130	-	-
L03 Corridor	130	-	-
L03 Exit Bay	130	-	-
L03 Lobby	130	-	-
L03 Theatre 18	130	-	-
L03 Corridor	130	-	-
L03 Theatre 18 Technical	130	-	-
L03 Anaesthetic (Theatre 18)	130	-	-
L03 Bay 1	130	-	-
L03 Bay 2	130	-	-
L03 Bay 3	130	-	-
L03 Bay 4	130	-	-
L03 Staff Base	130	-	-
L03 Bay 6	130	-	-
L03 Bay 5	130	-	-
L03 Lobby	130	-	-
L03 Recovery Bays	130	-	-

The spaces in the building should have appropriate passive control measures to limit solar gains in summer

Zone	Solar gain limit exceeded? (%)	Internal blinds used?
L02	NO (-58.6%)	NO
L03 Lobby	N/A	N/A
L03 Clean Utility	N/A	N/A

Zone	Solar gain limit exceeded? (%)	Internal blinds used?
L03 Dirty Utility	N/A	N/A
L03 Lobby	N/A	N/A
L03 Lobby	N/A	N/A
L03 Linen Store	N/A	N/A
L03 Anaesthetic (Theatre 17)	N/A	N/A
L03 Theatre 17 Technical	N/A	N/A
L03 Theatre 17	N/A	N/A
L03 Consumables Store	N/A	N/A
L03 Control Room	N/A	N/A
L03 Theatre Store	N/A	N/A
L03 Corridor	N/A	N/A
L03 Exit Bay	N/A	N/A
L03 Lobby	N/A	N/A
L03 Theatre 18	N/A	N/A
L03 Corridor	N/A	N/A
L03 Theatre 18 Technical	N/A	N/A
L03 Anaesthetic (Theatre 18)	N/A	N/A
L03 Bay 1	N/A	N/A
L03 Bay 2	N/A	N/A
L03 Bay 3	N/A	N/A
L03 Bay 4	N/A	N/A
L03 Staff Base	N/A	N/A
L03 Bay 6	N/A	N/A
L03 Bay 5	N/A	N/A
L03 Lobby	N/A	N/A
L03 Recovery Bays	N/A	N/A

Regulation 25A: Consideration of high efficiency alternative energy systems

Were alternative energy systems considered and analysed as part of the design process?	YES
Is evidence of such assessment available as a separate submission?	YES
Are any such measures included in the proposed design?	YES

Technical Data Sheet (Actual vs. Notional Building)

Building Global Parameters

	Actual	Notional
Floor area [m^2]	1335.1	1335.1
External area [m^2]	2184.9	2184.9
Weather	LON	LON
Infiltration [m^3/hm^2@ 50Pa]	1	3
Average conductance [W/K]	352.89	767.17
Average U-value [W/m^2K]	0.16	0.35
Alpha value* [%]	27.03	10

* Percentage of the building's average heat transfer coefficient which is due to thermal bridging

Building Use

% Area	Building Type
	Retail/Financial and Professional Services
	Restaurants and Cafes/Drinking Establishments/Takeaways
	Offices and Workshop Businesses
	General Industrial and Special Industrial Groups
	Storage or Distribution
	Hotels
100	**Residential Institutions: Hospitals and Care Homes**
	Residential Institutions: Residential Schools
	Residential Institutions: Universities and Colleges
	Secure Residential Institutions
	Residential Spaces
	Non-residential Institutions: Community/Day Centre
	Non-residential Institutions: Libraries, Museums, and Galleries
	Non-residential Institutions: Education
	Non-residential Institutions: Primary Health Care Building
	Non-residential Institutions: Crown and County Courts
	General Assembly and Leisure, Night Clubs, and Theatres
	Others: Passenger Terminals
	Others: Emergency Services
	Others: Miscellaneous 24hr Activities
	Others: Car Parks 24 hrs
	Others: Stand Alone Utility Block

Energy Consumption by End Use [kWh/m^2]

	Actual	Notional
Heating	3.84	2.54
Cooling	3.97	10.36
Auxiliary	95.71	93.44
Lighting	16.47	16.39
Hot water	3.91	6.05
Equipment*	166.15	166.15
TOTAL**	**123.9**	**128.78**

* Energy used by equipment does not count towards the total for consumption or calculating emissions.
** Total is net of any electrical energy displaced by CHP generators, if applicable.

Energy Production by Technology [kWh/m^2]

	Actual	Notional
Photovoltaic systems	8.68	0
Wind turbines	0	0
CHP generators	0	0
Solar thermal systems	0	0
Displaced electricity	*8.68*	*0*

Energy & CO_2 Emissions Summary

	Actual	Notional
Heating + cooling demand [MJ/m^2]	136.61	131.43
Primary energy [kWh_{PE}/m^2]	169.96	189.48
Total emissions [kg/m^2]	15.64	17.29

HVAC Systems Performance

System Type		Heat dem MJ/m2	Cool dem MJ/m2	Heat con kWh/m2	Cool con kWh/m2	Aux con kWh/m2	Heat SSEEF	Cool SSEER	Heat gen SEFF	Cool gen SEER
[ST] Constant volume system (variable fresh air rate), [HS] ASHP, [HFT] Electricity, [CFT] Electricity										
	Actual	7.9	76.2	0.6	4	89	3.8	5.25	2.57	5.25
	Notional	26.4	108.1	2.6	10.6	91.6	2.78	2.84	----	----
[ST] Split or multi-split system, [HS] ASHP, [HFT] Electricity, [CFT] Electricity										
	Actual	1492.1	44	103.4	2.5	241.5	4.01	4.8	3.2	6.42
	Notional	0	52.6	0	5.1	120.8	2.78	2.84	----	----
[ST] Split or multi-split system, [HS] ASHP, [HFT] Electricity, [CFT] Electricity										
	Actual	1567.7	41.4	85.4	1.8	241.5	5.1	6.46	4.04	8.65
	Notional	0	45.5	0	4.4	120.8	2.78	2.84	----	----
[ST] Split or multi-split system, [HS] ASHP, [HFT] Electricity, [CFT] Electricity										
	Actual	1477.6	45.7	102.4	2.6	241.5	4.01	4.8	3.2	6.42
	Notional	0	54.4	0	5.3	120.8	2.78	2.84	----	----

Key to terms

Heat dem [MJ/m2]	= Heating energy demand
Cool dem [MJ/m2]	= Cooling energy demand
Heat con [kWh/m2]	= Heating energy consumption
Cool con [kWh/m2]	= Cooling energy consumption
Aux con [kWh/m2]	= Auxiliary energy consumption
Heat SSEFF	= Heating system seasonal efficiency (for notional building, value depends on activity glazing class)
Cool SSEER	= Cooling system seasonal energy efficiency ratio
Heat gen SSEFF	= Heating generator seasonal efficiency
Cool gen SSEER	= Cooling generator seasonal energy efficiency ratio
ST	= System type
HS	= Heat source
HFT	= Heating fuel type
CFT	= Cooling fuel type