The Palestra Building
London, England

Architectural Renderings compliments of Alsop Architects

Technical Assignment 2

Becca Allen
The Pennsylvania State University
Architectural Engineering
Mechanical Option
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Table of Contents

I. Executive Summary
II. Background
III. LEED Analysis
IV. Envelope Compliance with AHSRAE Std 90.1
V. Lighting Compliance with ASHRAE Std 90
VI. Mechanical Space Impact
VII. Fuel Utilization Data/ Building Emissions
VIII. Load and Energy Estimates
IX. Annual Operating Costs
X. Conclusion
XI. References

I. Executive Summary

The purpose of this report is to take a closer look at the mechanical structures of the Palestra Building looking at the design's environmental consciousness according to the LEED program, power consumption densities according to ASHRAE Standard 90, lost rentable space due to mechanical systems, fuel utilization data, emissions, and load and energy analysis. A comprehensive analysis can then be completed with respect to 'the bottom line': money. And comparisons can be made with similar projects of scope and size to ensure efficiency on the project.

The Palestra Building was designed to qualify for a 'Very Good' rating on the BREEAM scale, which is the UK's equivalent to the US's LEED initiative. Palestra received 57% of the points on the BREEAM scale (57points of a possible 90 points), but only received 42% of the points (29 of 69 points) according to LEED. With 29 points the Palestra Building is certified as a LEED building, but it does not qualify for the Silver, Gold, or Platinum certifications.

The envelope was found to be compliant with ASHRAE Standard 90.1. The Palestra Building was found to have 44.3% glazing on its façade which is less than the 50% maximum as stated in Standard 90. The façade's shading coefficients were also calculated with the maximum values for the North façade being 0.36 and all other sides being 0.25. The glazing on all sides of Levels 0-8 (the 'Bottom Box') and the North side of the Levels 9-12 (the 'Top Box') complied with the Standard, while the South/East/West facing areas on Levels 9-12 did not pass with a value of 0.34 > 0.25.

The lighting consumption of Palestra was also calculated according to ASHRAE Standard 90. According to the 'Space by Space' method outlined in the Standard, only four of the six typical spaces divided by activity passed. This included the water closets, reception area, plant room, and corridors. The spaces that did not pass were the Office Space (15.75 W/m^2 > 11.83 W/m^2) and below grade Car Park (3.5W/m^2 > 2.15W/m^2). According to the 'Building Area Method' analysis, the power overall lighting power density for the building I 14.75 W/m^2 which is significantly greater than the 10.7 W/m^2 (1.0 W/ft^2) maximum value outlined in Std. 90. The Palestra Building does not comply with ASHRAE Standard 90's lighting power density regulations.

The Palestra Building has a rooftop chiller plant, a basement boiler plant, and an additional major mechanical space on the ground level to service the lobby area. It was found that 10.56% (3450.11 square meters) of the building's gross internal area is lost due to these systems. The design team was aiming for a value between 6 and 11% for mechanical spaces, so while this is on the higher end of the range it is still considered 'good design.'

The Palestra Building's mechanical systems contain 4 gas-fired boilers, where three run at full capacity and one is for redundancy. There are also 7 packaged chillers, with 6 running at full capacity. Each chiller has an electrical consumption of 186kW. The total gas intake for the Palestra Building is 212 m^3/h. Through a full building simulation using Carrier's Hourly Analysis Program (HAP) version 4.20, it was found that the design tonnage and supply rate (cfm) per air handling unit were comparable with the HAP output. However the ventilation rates for the units serving the office spaces according to HAP were double the rate of the design flow. This suggests a difference between the American and British building assumptions and will be discussed further in the conclusion.

The design peak loads for the Palestra Building are 1796kW (heating), 3871kW (cooling), and 3051kW (electrical). The natural gas intake is sized at 212 m^3/h, providing 6.64E+06 Therms per annum. Each of the seven chillers is also sized to provide 157 tons of air conditioning each. To accurately calculate the emissions for the electrical generation mix in the UK, the following percentages were used
Coal: 34%, Oil: 2%, Natural Gas: 37%, Nuclear: 23%, Hydro/Wind: 4%. The final pollutant concentrations were found to be 3.49E+4 lbm of SO_x, 1.64E+4 lbm of CO_2, and 7.24E+6 of NO_x.

Finally, the operational and first costs for the mechanical systems were calculated. The building's mechanical first costs came in at £9.9 million which is 15% of the total project cost. According to the HAP cost analysis the annual operating costs will average £200,000 annually. These values are based on the assumption that the building owners will choose to use British Gas as their electrical and gas supplier. With such a large commercial consumer, the nominal rate could improve.

II. Background

The mechanical systems in the Palestra Building include the following:

- Cooling
  Cooling is provided through a chiller plant located on the roof and consisting of seven packaged air-cooled chiller units, six of which run at full load daily, while the seventh serves as a backup unit. These units run the building's chilled water system fed to the fan coil units and cooling coils in the air handling plant. The primary and secondary constant temperature pumps and circuits are located on the room next to the chiller units.
- Heating
  Heating is provided through a gas-fired central boiler. The boiler room is located in the basement, and runs on four boilers, three of which run at 100% to met the daily demands while the fourth is a backup during times of maintenance or it can be used as a 'booster boiler' to generate the morning warm-up. These boilers service a low temperature hot water system fed to AHU ventilation systems, fan coil units, and heater batteries.
- Humidification
  The Palestra Building is located in London, England, a location where humidity levels are not a critical concern for 60% of the year. However, during the winter months when the humidity drops down occupants can begin to experience dry eyes and throats, similar to the symptoms of Sick Building Syndrome (SBS). To maintain the humidity level between 35-65% there is a combination of chilled ceilings and the fan coil units with a VAV system.

III. LEED Analysis

The Leadership in Energy and Environmental Design standards for rating Green Building Design is the American document that sets the national standard for Green Buildings. The aim of the LEED program is to encourage an improvement in the occupant well-being, environmental performance, and the economic returns of buildings through innovative standards and technologies. Green design is also commonly known as Sustainable Design, where a strong emphasis is placed on the ability of the current design to be able to adapt to the future needs of the building and its occupants. This will increase the building's life span and thus the returns that the owner can expect on his investment.

The LEED rating system is a point system based characteristics in six main areas: sustainable sites, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality. Depending on your attention to these areas in the design a building can achieve up to 69 points.

LEED Rating System

26-32 points: certified as a LEED Building
33-38 points: Silver certification,
39-51 points: Gold certification
52-69 points: Platinum certification

The Palestra was not designed to meet the LEED standards; however it was designed to the UK equivalent for Non-Residential buildings, BRE's Environmental Assessment Method (BREEAM). Under the BREEAM Palestra received a 'Very Good' Rating. It is important to note that while a main design objective for this project was to obtain a 'Good' or 'Very Good' rating on the BREEAM scale. BREEAM places more emphasis on transportation to the site, and with the Palestra Building being 500m from a tube stop, many additional points were gained for BREEAM that do not apply to LEED.

Palestra is being scored under the LEED design standard as well as part of an ongoing study into the similarities and differences between the building design codes in the US and the UK.

Table 3.1 shows the results of the LEED analysis. The Palestra Building received 29 points out of a possible 69, gaining LEED certification.

Table3.1 LEED Certification Analysis
Palestra Building

Credit No	Category	Possible Points	Points Received	Comments
SUSTAINABLE SITES		**14**		
Prereq 1	Erosion & Sediment Control	Required		
1	Site Selection	1	1	Located in Central London
2	Urban Redevelopement	1	1	The development has made efficient use of the site with a high density of people accommodated on the site.
3	Brownfield Redevelopement	1	1	The development makes use of a large brown-field site which helps reduce pressure to use green-field sites.
4.1	Alt Transport: Public Transport Access	1	1	Central location of the development near to public amenities such as shops transport links, local health centres leisure facilities, communication services, hospitals and cultural facilities.
4.2	Alt Transport: Bicycle Storage & Changing Rooms	1	1	Secure, covered spaces for bicycles.
4.3	Alt Transport: Alt Fuel Vehicles	1		
4.4	Alt Transport: Parking Capacity	1	1	Secure, covered spaces for bicycles and cars are provided.
5.1	Reduced Site Disturbance: Protect/Restore Open Space	1	0	
5.2	Reduced Site Disturbance: Development Footprint	1	1	Given the multi-storey nature of the development schemes this objective is achieved.
6.1	Stormwater Management: Rate and Quantity	1	1	A Sustainable Urban Drainage System has been installed to reduce storm-water run-off by more than 50%.
6.2	Stormwater Management: Treatment	1	1	The primary role of the site drainage scheme will be to ensure the quality of site runoff and the attenuation of runoff on site in order to reduce peak flows and suspended solids in runoff discharge.
7.1	Heat Island Effect: Non-Roof	1		
7.2	Heat Island Effect: Roof	1		
8	Light Pollution Reduction	1	1	to reduce the amount of light spillage to comply with the planning requirements, the amount of light being emitted from the luminaires adjacent to the south façade should be reduced which will require for some of the luminaires adjacent to the south façade to be switched off at night between 7pm and 7am. The effect of this will be to keep the lights spillage on Rowland Hill house down to 1 lux
WATER EFFICIENCY		**5**		
1.1	Water Efficient Landscaping: Reduce by 50%	1	0	
1.2	Water Efficient Landscaping: No Potable Use or No Irrigation	1	0	
2	Innovative Wastewater Technologies	1	1	Rainwater collection scheme, harvesting rainwater from the roof for flushing WCs. Waste generated during building operation is being managed and reduced by waste-stream management, including: the separation, storage and recycling of waste.
3.1	Water Use Reduction: 20% reduction	1	1	The demand for water is being reduced through measures including: spray taps and a comprehensive leak detection system
3.2	Water Use Reduction: 30% reduction	1	1	Water efficient appliances have the potential of reducing the amount of water consumed by as much as 70% in comparison to standard fittings and appliances.

ENERGY & ATMOSPHERE		**17**		
Prereq 1	Fund. Bldg. Systems Commisioning	Required		
Prereq 2	Min. Energy Performance	Required		
Prereq 3	CFC Reduction in HVAC&R Equipment	Required		CFC-free materials For the areas where refrigerants are specified, these will be of zero ODP (Ozone Depleting Potential). Also, the intention will be for the GWP (Global Warming Potential) to be as low as possible, to minimise the impact on the environment.
1	Optimize Energy Performance	1 to 10		Measures for reducing energy demand during the operation of the development include: centralised plant to improve energy efficiency
2.1	Renewable Energy, 5%	1	0	
2.2	Renewable Energy, 10%	1	0	
2.3	Renewable Energy, 20%	1	0	
3	Additional Commissioning	1		
4	Ozone Depletion	1	1	The chillers used in the building contain refrigerants with an Ozone Depletion Potential of zero. • The boilers are ultra-low-NOx-emitting. Reducing the emission of NOx gases (various oxides of nitrogen) reduces the generation of acid rain and local air pollution and impact on climate change.
5	Measurement & Verification	1	1	Refrigerant leak-detection system is installed to reduce the risk of pollution resulting from leaks.
6	Green Power	1	0	
MATERIALS & RESOURCES		**13**		
Prereq 1	Storage and Collection of Recyclables	Required		Provision of storage space for recyclable materials (such as cans, cups, paper).
1.1	Building Reuse: Maintain 75% of existing shell	1	0	
1.2	Building Reuse: Maintain 100% of existing shell	1	0	
1.3	Building Reuse: Maintain 100% existing shell and 50% non-shell	1	0	
2.1	Construction Waste Management: Divert 50%	1	1	Management of waste: waste segregation and disposal has been undertaken during the construction phase. During operation, staff will be encouraged to recycle waste through the provision of appropriate collection facilities on site.
2.2	Construction Waste Management: Divert 75%	1		
3.1	Resource Reuse: Specify 5%	1	1	Recycled aggregate (crushed concrete) has been used in the piling mat.Disposal of waste will is in line with environmental good practice, and potential re-use of materials before disposing them is considered.
3.2	Resource Reuse: Specify 10%	1		
4.1	Recycled Content: Specify 5%	1	1	All unwanted materials from the site during construction will be recycled or disposed of in a way that is environmental good practice and compliant with regulations.
4.2	Recycled Content: Specify 10%	1		
5.1	Local/Regional Materials: 20% Manufactuered locally	1	1	Materials were selected for long life and low maintenance and, where possible, were sourced locally.
5.2	Local/Regional Materials: of 20% in MRc5.1, 50% Harvested Locally	1		
6	Rapidly Renewable Materials	1		
7	Certified Wood	1	1	All solid timber and timber panel products were obtained from sustainable, well-managed sources.

INDOOR ENVIRONMENTAL QUALITY		15		
Prereq 1	Minimum IAQ Performance	Required		
Prereq 2	Environmental Tobacco Smoke (ETS) Control	Required		
1	Carbon Dioxide Monitoring	1	0	
2	Ventilation Effectiveness	1		ASHRAE 129-1997
3.1	Construction IAQ Mgmt Plan: During Construction	1	1	Internal air quality has been carefully considered by positioning of air inlets for ventilation away from sources of external pollution.
3.2	Construction IAQ Mgmt Plan: Before Occupancy	1	1	Before the practical completion the design team will explain and demonstrate the purpose, function and operation of the installations including all items and procedures listed in the O&M manual to the Employer's maintenance staff including training of 5 members of staff over 10 days.
4.1	Low-Emitting Materials: Adhesives and Sealants	1	1	Environmentally friendly and healthy materials: the building gained the maximum BREEAM credits available for use of low-environmental impact construction materials. The use of toxic and ozone-depleting materials has been avoided. • Earth materials: e.g. clay mortars, earth blocks etc.: low embodied energy, zero toxicity
4.2	Low-Emitting Materials: Paints	1	1	Natural paints (not oil-based): lower emissions after construction & during occupation
4.3	Low-Emitting Materials: Carpet	1	1	
4.4	Low-Emitting Matericals: Composite Wood	1		
5	Indoor Chemical and Pollutant Source Control	1		
6.1	Controllability of Systems: Perimeter	1	1	Fully integrated Building Management System
6.2	Controllability of Systems: Non-Perimeter	1	1	Fully integrated Building Management System
7.1	Thermal Comfort: Comply with ASHRAE 55-1992	1		
7.2	Thermal Comfort: Permanent Monitoring System	1	1	Energy-efficient lighting and controls. Local control of the internal environment has been provided for occupants wherever possible, including local control of lighting, local thermal zone control, and control of glare by means of internal blinds.
8.1	Daylight & Views: Daylight 75% of spaces	1	1	The façade would allow sufficient daylight to enter the space so that for a high percentage of the time the electric lighting in the perimeter areas could be switched off if, resulting to energy savings.
8.2	Daylight & Views: Views for 90% of spaces	1	0	
INNOVATION & DESIGN PROCESS		**5**		
1.1	Innovation in Design	1		
1.2	Innovation in Design	1		
1.3	Innovation in Design	1		
1.4	Innovation in Design	1		
2	LEED Accredited Professional	1		
PROJECT TOTALS		**69**	**29**	**LEED Certified**

IV. Envelope Compliance with AHSRAE Std 90.1

Section 5 of ASHRAE's Standard 90.1-2004 regulates the energy efficiency of a building's envelope by providing minimum requirements for the heat transfer and insulation values of the façade. There are two methods to determine a façade's compliance, one is a Prescriptive Method and the other is a Trade-Off Option. Only the prescriptive method will be used in this analysis.

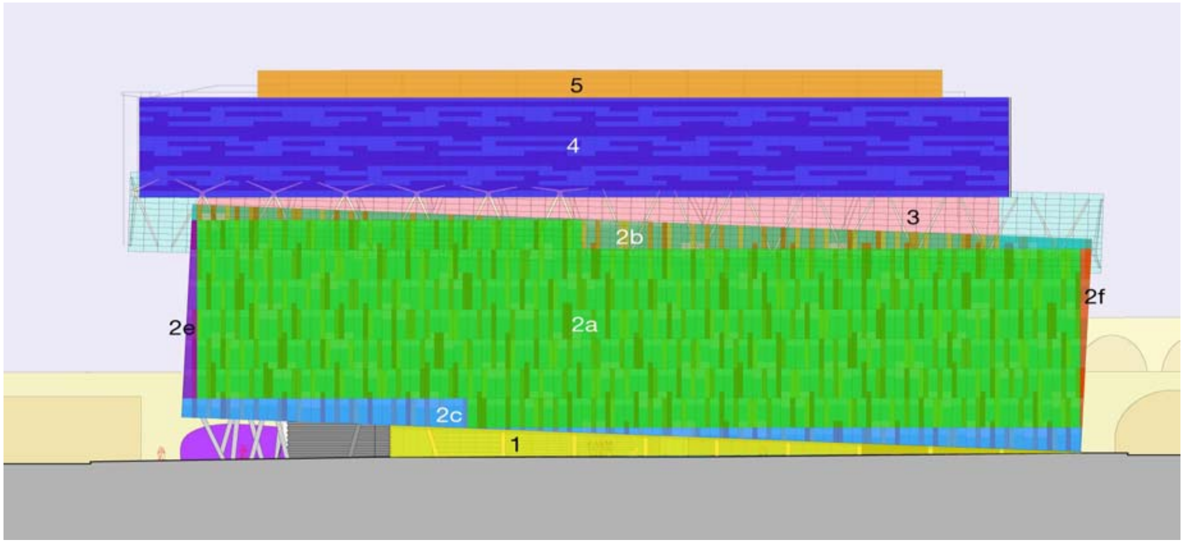
The Palestra Building is located in London, England. According to Table B-3 and B-4 this puts the building in Zone 4A. Table D-3 gives the number of heating degree days (HDD@65F) to be 5015 and the number of cooling degree days (CDD@50F) to be 1894. These values fall just outside of the thermal criteria set in Table B-4: CDD shall be less than 4500 and HDD shall be less than 3600. However, because the difference is only 515 heating degree days, the values calculated according to Standard 90.1-2004 shall be permissible. A more detailed explanation of the Heat Loss values for each level can be found in Appendix A.

Table 4.1 details the areas of glazing on the façade of the Palestra Building. The glazing design did change somewhat since this breakdown, however the follow diagrams give a good idea of the intricacy of the building envelope.

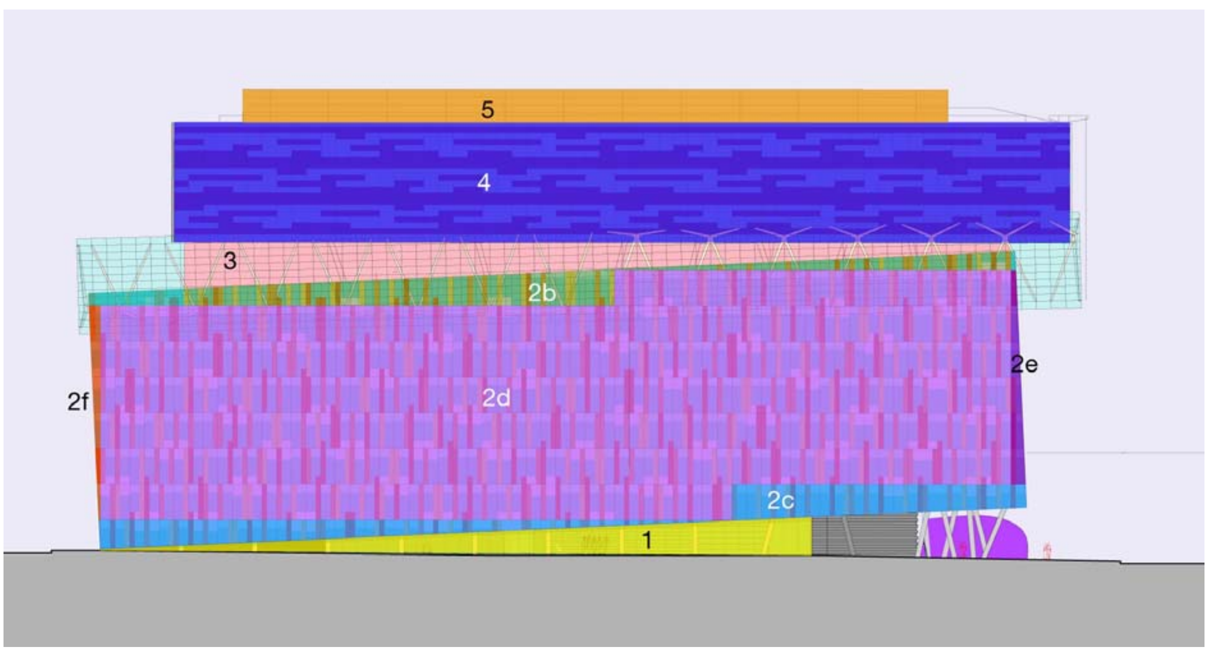
Table 4.1

by type.

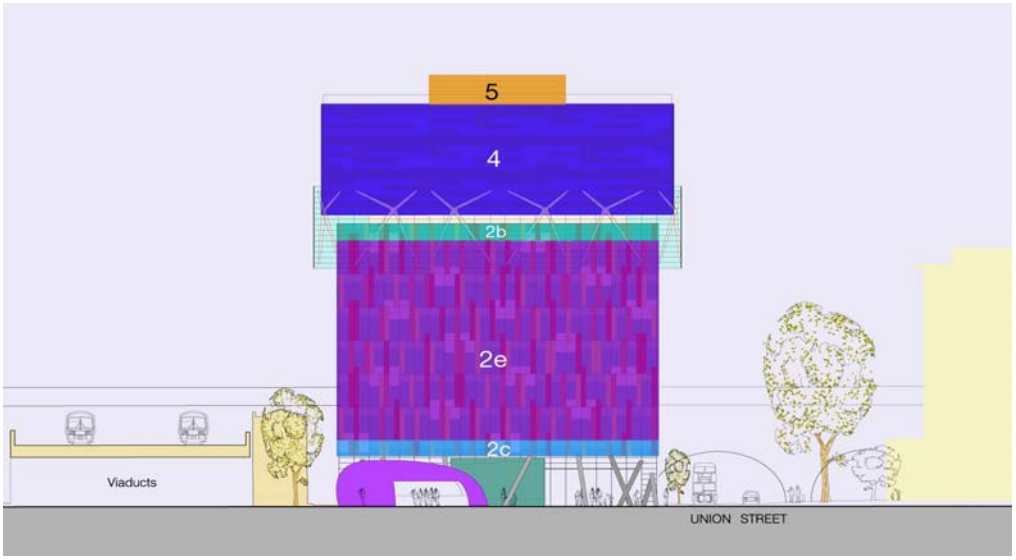
Area #	Description	Framing system	Glazing type (see 5)	Area (m^2)
1	Ground Floor Glazing	Stick system	C	314
2a	Bottom Box glazing South facade	Unitised frame	A	2,050
2b	Bottom box balustrade at terrace level	Unitised frame, custom bespoke units, shaped to meet upper edge of box.	B	505
2c	Bottom Box glazing South façade, void unoccupied areas behind	Unitised frame, custom bespoke units, shaped to meet lower edge of box.	A	684
2d	Bottom Box glazing North façade, acoustic glazing.	As 2a	D	2,050
2e	Bottom Box glazing West façade, acoustic glazing.	Unitised frame, edge detail to account for inward elevation slope	D	842
2f	Bottom Box glazing East facade	Unitised frame, edge detail to account for outward elevation slope	A	772
3	Terrace Glazing	Stick system	C	988
4	Top Box Glazing	As 2a	E	2,988
5	Roof plant enclosure	Proprietary screening system	-	506



South Elevation



North Elevation

West Elevation

East Elevation

Walls

Table 5.5-4 sets the minimum U-values needed for the envelope. Describing Palestra's design as a 'Metal Building' yields a maximum U-value of 0.124 W/m^2K. As shown in Figure 5.1 the Opaque Wall Assembly has a U-Value of 0.34 W/m^2K. The Palestra's design U-value is much greater than the maximum value required by Standard 90.1.

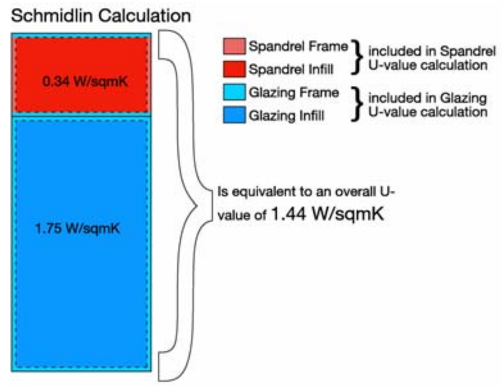


Figure 5.1 Typical Wall U-Values

Roof

According to Table 5 found in Section 2 of Approved Document L, the design U-value for Palestra is 0.2W/m^2K. However, 0.2W/m^2K is still much greater than the U-Value required by ASHRAE for a 'Metal Building,' 0.065. The roof of the Palestra Building does not comply with ASHRAE Standard 90.1.

Glazing

Section 5.5 of ASHRAE's Standard 90 concerns the compliance of glazing percentages. It limits the allowable vertical fenestration area to less than 50% of the gross façade area, and the skylight fenestration is limited to 5% of the roof's gross area. The Palestra Building has no roof lights. The façade breakdown is summarized in Table 4.2.

The Palestra Building has 44.3% glazing on its façade and therefore complies with ASHRAE's Standard 90.1. It is important to note that it was not designed to ASHRAE Standards, but rather Approved Document L as published by the Deputy Prime Minister of England. From the building's compliance with both codes, we can assume that the standards follow similar guidelines.

Table 4.2 Palestra Envelope Façade Areas

Ground Floor	**Area, m^2**
Insulation	100
Glazing	314
Total	414
% Glazing	75.85%
Lower Box' Levels 0-8	
Vertical Insulation Strips	1780.9

Floor Edge Insulation (firestop@200mm downstand)	309.3
Glazing	6903
South Facing	2050
North Facing	2050
West Facing	842
East Facing	772
balustrade at terrace level	505
glazing South façade, void unoccupied areas behind	684
Insulation	2090.2
Total	17986.4
% Glazing	38.38%
Top Box' Levels 9-11	
Insulated 700mm upstand	533
Floor Edge Insulation (firestop @900mm downstand)	895
Glazing	2988
Insulation	1428
Total	5844
% Glazing	51.13%
Terrace	
Glazing	988
Total	988
%Glazing	100.00%
TOTALS	
Total Glazing	**11193**
Total Insulation	**14039.4**
Total Area of Façade	**25232.4**
Total % Glazing	**44.36%**

Solar Heat Gain Coefficient
Section 9 of ASHRAE Standard 90.1-2004 regards the allowable shading heat gain coefficient (SHGC) for a building façade. The typical U-value for the glazing on the Palestra Building is 1.75.

According to Table 5.5-4 of Standard 90.1-2004, the maximum allowable SHGC factor for the South, East, and West elevations is 0.25, while the maximum SHGC factor is 0.36 for the North Side. Due to the large percentage of glazing on the Palestra Building, it was important for the design team to maintain a SHGC Factor of 0.3 or better. Below are the calculated Shading Coefficients.

Table 4.3 Palestra Envelope Shading Coefficients

Lower Box' Levels 0-8	Area, m^2	Shading Coefficient	All Elevations, 0.25 Max	North Elevation, 0.36 Max
Solid panel	2.4	0		
Blue body tint glazing	3.075	0.35		
Total	5.475	**0.20**	**PASS**	**PASS**
Top Box' Levels 9-12				
Solid panel	0.9	0		
solar control glazing	2.75	0.52		
fritted glazing	1.375	0.32		
total	5.475	**0.34**	**FAIL**	**PASS**

The terrace level has no shading coefficient for its glazing because 80% of its area is shaded by the overhang of 'top box.'

The results listed in Table 4.3 confirms that the SHGC Factor of the Palestra Building's 'Lower Box' of its façade design does meeting ASHRAE Standards on all elevations. However, the coefficient for the 'Top Box' is only acceptable on the North elevation. Therefore, there will be high solar gains on 'Top Box' on the East, West, and South elevations than suggested by the code. The Palestra Building does not meet ASHRAE Standard 90.1.

V. Lighting Compliance with ASHRAE Std 90

Section 9 of ASHRAE Standard 90-2004 concerns the lighting design and power consumption of a building. There are two methods of compliance described in this section: the Building Area Method and the Space-by-Space Method. The Space-by-Space Method is a more detailed calculation and designates the power density for each space's function and summing them for the Overall Power consumption, while the Building Area Method is more general and only determined by the Building's total power consumption divided by the area. Both methods will be used in this analysis.

Palestra's primary space function is for office space. However, the final tenants' fit outs have not yet been finalized and are based on an average of 15 W/m^2. Lighting to the open plan office spaces will be provided using recessed modular fluorescent luminaries, fitted with high frequency control gear and providing brightness management to increase its efficiency. To meet the target power density an efficiency of 3.5 W/m^2/100lux was maintained throughout the building.

Space-by-Space Method

Table 5.1 summarizes the Space-by-Space lighting density calculations. As you can see only 4 of the 6 spaces passed. The lighting for the office spaces is 33% higher than ASHRAE's suggestion, while the lighting in the car park is 63% higher. Again, these discrepancies could be accounted for by the different codes used for the design. The design of Palestra was based strongly on standards for 'Good Design' outlined in Chartered Institution of Building Services Engineers (CIBSE). However, Palestra does not meet ASHRAE Standard 90 section 9 using the Space-by-Space analysis.

Table 6.1 Lighting Design Loads

Space	Area, m^2	Lighting, lux	Efficiency, W/m^2/100lux	Lighting/Area, W/m^2	Lighting, Watts	Std 90, W/ft^2	Std 90, W/m^2	
Office Space	31606	450	3.5	15.75	497794.5	1.1	11.83	Fail
Water Closets	1125	150	3.5	5.25	5906.25	1	10.75	Pass
Reception	772	300	3.5	10.5	8106	1.3	13.4	Pass
Plant Room	2578.31	150	3.5	5.25	13536.128	1.2	12.9	Pass
Car Park	4942	100	3.5	3.5	17297	0.2	2.15	Fail
Corridors	608	200	3.5	7	4256	0.7	7.53	Pass
TOTAL	**41631.31**				**546895.88**			

Note: The total area calculated for Lighting Load (41,631.31 m^2) is greater than the Building's office area (37,098 m^2) because the area of the below grade car park was include for lighting purposes, but does not compute into the gross office area.

Building Area Method

Power Density = Total Lighting Power/Total Floor Area
= 546895.88W/37098m^2
= 14. 74 W/m^2

Using the Building Area Method the Light Power density was found to be 14.74 W/m^2 which is very close to the target density at 15 W/m^2. However for an office building ASHRAE says the target Lighting Density should be 10.75 W/m^2 (1.0 W/ft^2). Therefore the Palestra Building Fails the Building Area Method and does not meet ASHRAE Standard 90 section 9.

VI. Mechanical Space Impact

Lost Rentable Space

The Palestra Building is a large scale speculative office building therefore its design was strongly driven by maximizing the net rentable space so that the developers can maximize their return.

Table 6.1 Mechanical Space

Level	Space	% Area to GIA	Area, m^2
Basement	Plant Room	1.98	734.54
Roof	Plant Room	3.72	1380.05
All Floors	Riser		
	Miscellaneous	0.8	296.78
	Public Health	0.3	111.29
	Electrical	0.5	185.49
	Mechanical	2	741.96
All Floors	Core 1	0.31	115.00
	Core 2	0.45	167.30
	Core 3	0.50	183.75
Total		**10.56**	**3450.11**
GIA, m^2	*37098*		

As shown, 10.5 % of the Palestra Building's gross area is consumed by mechanical space. To ensure that Palestra was maximizing the use of its mechanical spaces in the minimal amount of space the design team compared it's percentage of mechanical space to those of similar projects with a similar size and scope. Analyzing 10 previous projects the mechanical spaces ranged from 6.17-11.98% of the gross area. That places the Palestra within that range, thus ensuring that good design standards were maximized.

First Costs

Table 6.2 Mechanical Firsts Costs

Equipment	Quantity	Cost
HEATING SYSTEMS		
Gas Supply	37,394 m^3	£1,037,744.00
700kw Gas-Fired Boiler	4	£46,600.00
Boiler Flue System	1	£27,780.00
LTHW Pumps	1	£11,715.00

Primary Distribution - Heating	37,394 m^2	£299,152.00
Secondary Distribution - Heating	26,904 m^2	£591,888.00
COOLING SYSTEMS		
553kw Air-Colled Chiller Package	7	£359,240.00
CHW Pumps	1	£18,165.00
Primary Distribution - Cooling	37,394 m^2	£373,940.00
Secondary Distribution - Cooling	26,904 m^2	£1,022,352.00
Fan Coil Units		
Size 15 - Perimeter Office Areas	343	£303,554.00
Size 9 - Internal Office Areas	394	£292,741.00
Size 6 – Lobbies	22	£16,346.00
Carrier 30RH - 39 heat pumps (Lobby)	1	£11,700.00
Fan Coils	6	£5,310.00
AIR SYSTEMS		
AHUs – Office	2	£170,000.00
Toilet Extract Fans	37,394 m^2	£74,788.00
Supply/Extract Ductwork	37,394 m^2	£373,940.00
Constant Volume Box	176	£80,960.00
Secondary Ductwork to Fan Coils	26,904 m^2	£1,022,352.00
Basement Car Park Ventilation	1,227 m^2	£50,307.00
Plant Room Ventilation	1,235 m^2	£56,810.00
1500x1000mm motorised damper and grille for smoke clearance	98	£171,500.00
CONTROLS		
Control Installation to Mech Systems with Interface	1	£603,860.00
TRANSPORTATION		
1600kg/21 Person passenger lift @ 1.6m/s serving 13 levels	6	£1,440,000.00
1600kg/21 Person passenger lift @ 1.6m/s serving 14 levels	1	£260,000.00
3000kg/40 person goods lift@1.6m/s serving 14 levels	1	£170,000.00

630kg/8 person fire fighting lift @ 1m/s serving 14 levels	2	£350,000.00
LABOUR		£660,996.00

TOTAL **£9,903,740.00**

Mechanical first costs for this project are £9.9 million which is approximately 15% of the total project's cost of £68 million.

VII. Load and Energy Estimates

The system contains 4 gas-fired boilers, where three run at full capacity and one is for redundancy. There are also 7 packaged chillers, with 6 running at full capacity. Each chiller has an electrical consumption of 186kW. The total gas demand for the Palestra Building is estimated to be 212 m^3/h (6644146 therms). This includes 10% for spare capacity and 32% for pre-heat capacity. The design calculations for the heating and cooling loads can be seen in Appendix B.

In this analysis three of the building's air handling units will tested using Carrier's Hourly Analysis Program version 4.20. The three units being tested are AHU-1 and AHU-2 which together service all of the office space, and AHU-7 which services the ground floor lobby. This decision was made because these areas account for 86% of the building floor area, and all of the exterior spaces. These results are also summarized in Appendix C.

Assumptions

Outdoor temperature

Winter -4°C saturated
Summer 29°C db, 20°C wb

Internal temperature

Offices: 22°C +/- 2
Toilets/Stairs
(summer) Uncontrolled
(winter) 18°C min, 22°C +/- 2

Air Movement

Winter 0.25m/s max
Summer 0.25m/s max

Relative Humidity:

Uncontrolled. Facility is to be built in to the office air handling units for the future addition of humidifiers.
No allowance to be provided for associated services (power or gas) in base building.

Table 7.1
AHU-1 (Office Space + Corridors)

	Capacity (ton)	Supply (L/s)	Ventilation (L/s)
Design	157	38813.64	17616
HAP	136.1	38826.99	31858.9

Table 7.2

AHU-2 (Office Space + Corridors)

	Capacity (ton)	Supply (L/s)	Ventilation (L/s)
Design	157	37726.66	17616
HAP	135.4	38590.09	31858.9

Table 7.3

AHU-7 (Reception)			
	Capacity (ton)	Supply (L/s)	Ventilation (L/s)
Design	31	3496.15	2064
HAP	11.3	2271.73	1964

The results of the HAP analysis are compared with the design values on the schedule in Tables 7.1, 7.2, and 7.3. For AHU-1 and AHU-2 the design ventilation is significantly less than what HAP calculated. The design calculations were based on the 'Good Practice' guidelines of 16 L/s/occupant and 12 m^2/occupant as published in the Chartered Institution of Building Services Engineers (CIBSE).

VIII. Fuel Utilization Data\ Building Emissions

The past two decades have seen a significant increase in environmentally friendly building designs. And with the predictions that the average temperature of the earth will rise 8 degrees due to Global Warming, great strides are being taken to lessen the effect we have on our environment. Therefore it is important that a building's pollution be analyzed before its construction in order to ensure good fuel utilization and low emissions. The results of this analysis are also instrumental in the determination of a 'Green Building' according to the LEED program. In this section the energy consumption, as well as the emissions from on-site electrical use will be determined.

The Palestra Building is currently under construction in London, therefore there are not any utility summaries or meter readings for the building. The estimated loads calculated by the design team will be used in this section and are summarized in Table 8.1.

Table 8.1
Breakdown of cooling loads

	BH proposed Brief		
Tenant Area Electrical Load			
Lighting	15 W/m2	18 VA/m2	
Equipment	30 W/m2	35 VA/m2	
Fan Coil units	6 W/m2	10 VA/m2	
total – Internal	**51 W/m2**	63 VA/m2	
Total floor area	26677	26677	
Tenant area load	**1,361 kW**	**1,679 kVA**	**2433 amp**
Landlord areas Electrical loads			
Lighting (automatic control)	7 W/m2	8 VA/m2	
General small power	2 W/m2	3 VA/m2	
Ventilation	40 W/m2	50 VA/m2	
Total	**49 W/m2**	**61 W/m2**	
Area	10717	10717	m^2
Landlord area load	**525 kW**	**651 kVA**	**943 amp**
Mechanical Plant for tenant areas			
Chiller Cooling Capacity (each)	**553 kW**		
Coefficient of Performance	3.3		
Chiller electrical Load (each)	**168 kW**	**186 kVA**	**270 amp**
No. of Duty chillers	6		
Total chiller load	**1,005 kW**	**1,117 kVA**	

10 No. Lifts	**120 kW**	**141 kVA**	
Tenant Area Ventilation Flow rate	35.6	m^3/s	
Tenant Supply & Extract fan load	**40 kW**	**47 kVA**	
Total	**1,691 kW**	**1,956 kVA**	**2835 amp**
Total			
Total	**3,051 kW**	**3,635 kVA**	**5268 amp**
4 x 1600amp supplies			**6400 amp**
Spare capacity		21%	1132 amp
(Includes 270 amp for additional chiller)			
Total per annum	**1113656.81**		

A full building simulation was performed using Carrier's Hourly Analysis Program, and the detailed results for each air handling unit are summarized in Appendix C.

The expected emissions for the Palestra Building due to electrical use are summarized in Table 6.2 and based on an annual consumption of 1.11E+06 kWh as calculated in Table 8.1. The percentages of fuel used to generate electricity in the UK taken from "National Statistics Online, Social Trend 34." The mass per kilowatt-hour of emissions are based on the average values found in the Electrical Generation mix in the US. Because the building is still under construction and there are no meter readings the data regarding the particulates for each fuel source could not be acquired for this analysis.

Chart 4: Fuel used in electricity generation

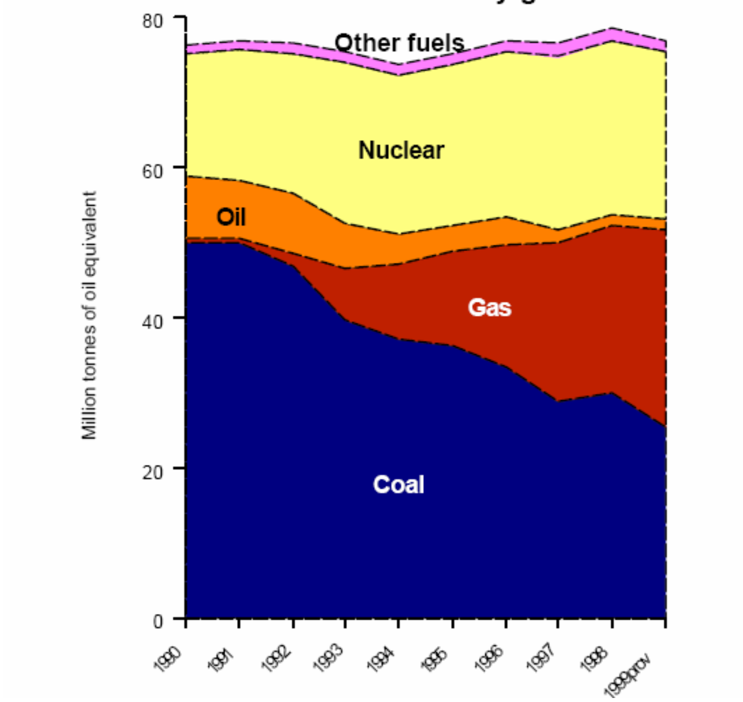


Table 8.2

"Electricity Generation: by Fuel used, EU Comparison 2001"

			lbm Pollutant/kWh				Total lbm Pollutant			
Fuel	kWh	% Total	Particulates	SO2/kWh	NO2/kWh	CO2/kWh	Particulates	SO2	NO2	CO2
Coal	3.79E+05	34.00%	--	1.28E-02	7.41E-03	2.15E+00	--	4.85E+03	2.81E+03	8.14E+05
Oil	2.23E+04	2.00%	--	1.54E-02	2.83E-03	2.11E+00	--	3.43E+02	6.30E+01	4.70E+04
Nat. Gas	4.12E+05	37.00%	--	1.35E-05	2.54E-03	1.34E+00	--	5.56E+00	1.05E+03	5.52E+05
Nuclear	2.56E+05	23.00%	--	0.00E+00	0.00E+00	0.00E+00	--	0.00E+00	0.00E+00	0.00E+00
Hydro/Wind	4.45E+04	4.00%	--	0.00E+00	0.00E+00	0.00E+00	--	0.00E+00	0.00E+00	0.00E+00
Totals	1.11E+06	100.00%	--	2.82E-02	1.28E-02	5.60E+00	--	3.14E+04	1.42E+04	6.24E+06
		Taking into account a transmission efficiency of 0.9, total emissions =						**3.49E+04**	**1.58E+04**	**6.93E+06**

A request for the actual mechanical equipment that has been specified for the building has been made, and this analysis will be updated as that data becomes available. Many of the estimations in this analysis could be strongly affected by the efficiency of the boilers, chillers, and cooling towers. For these calculations it was assumed that three of the four boilers were sized to carry an equal amount of the design heating load of 1796 kW that accounted for 10% spare capacity and 32% for preheat capacity (1533 MBH). Based on the energy input and output the overall efficiency was found to be approximately 70% for the boiler.

The chillers were simulated as W/C Centrifugal systems sized at 187 tons, which is one sixth of the total building cooling load with the seventh chiller sized equally for redundancy. The input power for each chiller was 168 kW as noted in the specifications.

There was very little information regarding the cooling towers. Therefore each cooling was simulated with a fan load at 0.1 kW/ton.

Table 8.3 summarizes the NOx, SOx, and CO2 emissions from the Palestra Building's use of natural gas. These values are based on a flow rate of 212 cubic meters per hour which is equivalent to 2.29E+5 kWh.

Table 8.3 Natural Gas Consumption Emissions

Natural Gas Consumption per annum (kWh)		SO2 (lbm/kWh)	CO2 (lbm/kWh)	NOx (lbm/kWh)	SO2 (lbm)	CO2 (lbm)	NOx (lbm)
229108.48	**(Design)**	1.35E-05	2.54E-03	1.34E+00	3.09E+00	5.82E+02	3.07E+05

Table 8.4 summarizes the total building emissions for Electrical and Gas consumption for a year.

Table 8.4 Total Energy Consumption Emissions

	SO2 (lbm)	CO2 (lbm)	NOx (lbm)
Natural Gas and Electricity per annum	**3.49E+04**	**1.64E+04**	**7.24E+06**

IX. Annual Building Operating Costs

The operating costs of a building play a very important role when selecting the mechanical system. The final system should have a nice balance between the first costs and the annual operating costs in order to maximize revenue and reduce the payback period. In addition, the environmental impacts of the building should also be analyzed as in section 8 to ensure that as the system gets older and less efficient it will not need to be replaced because it falls below the minimum EPA standards.

The utilities for the Palestra Building have not been finalized due to the fact that it is currently under construction. These utility estimates were found on the website for British Gas, which will most likely be the supplier to the Palestra Building due to their existing connection on the site.

British Gas

Electric
- £0.1119/kWh (first 900 units)
- £0.05896/kWh

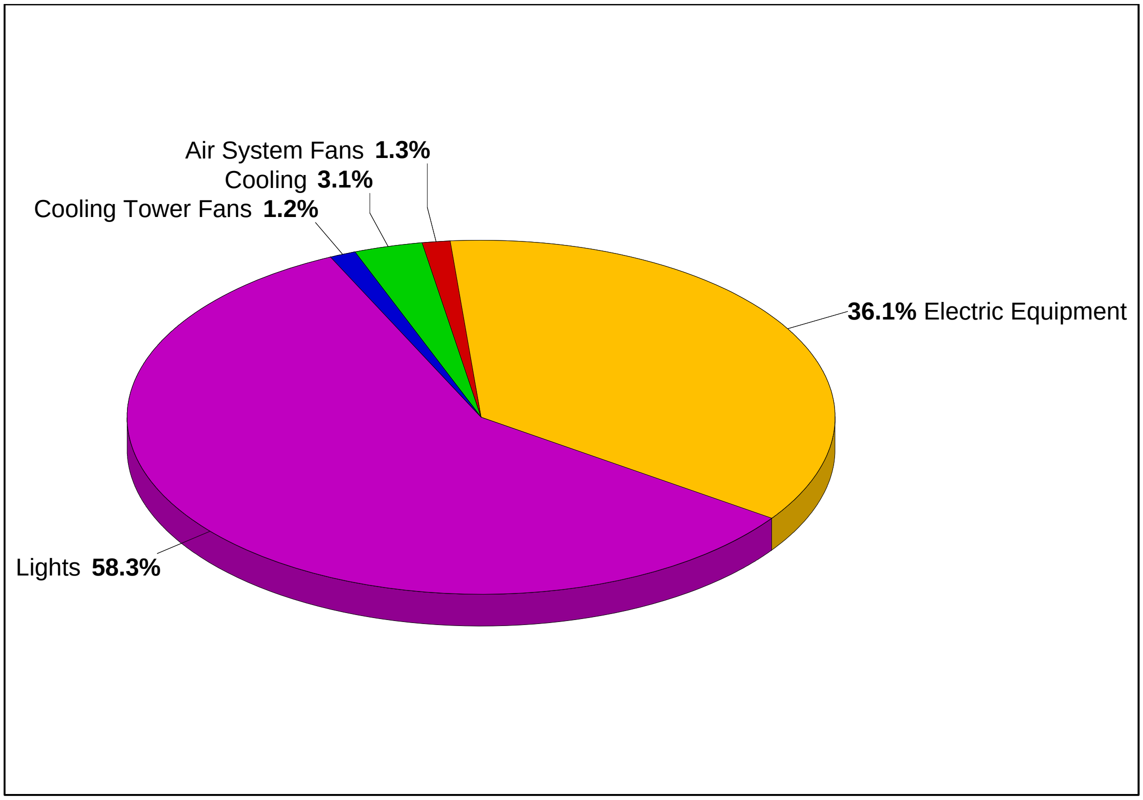
Gas
- £0.0295/kWh

Dual Fuel Standing Charge: £66.00

The load profile for these calculations was assumed to follow that of a typical office building with occupied levels from 7am – 7pm Monday through Friday, 12pm-5pm on Saturdays, and 12pm-3pm on Sundays and Holidays.

Chart 9.1 shows the breakdown of where all the operating costs being used. As expected the lighting load is the largest at approximately 60% of the operating costs. Typically the cooling tower fans would consumer a bit larger percentage of the building’s costs, however only three chillers are online in this analysis.

Chart 9.1



Air System Fans **1.3%**
Cooling **3.1%**
Cooling Tower Fans **1.2%**
36.1% Electric Equipment
Lights **58.3%**

Table 9.2 Annual Costs

Component	Palestra (£)
Air System Fans	2,649
Cooling	6,513
Heating	0
Pumps	0
Cooling Tower Fans	2,480
HVAC Sub-Total	**11,642**
Lights	121,122
Electric Equipment	75,036
Misc. Electric	0
Misc. Fuel Use	0
Non-HVAC Sub-Total	**196,158**
Grand Total	**207,800**

Table 9.3 Annual Costs

Component	Annual Cost (£)	(£/ft²)	Percent of Total (%)
Air System Fans	2,649	0.009	1.3
Cooling	6,513	0.021	3.1
Heating	0	0.000	0.0
Pumps	0	0.000	0.0
Cooling Tower Fans	2,480	0.008	1.2
HVAC Sub-Total	**11,642**	**0.038**	**5.6**
Lights	121,122	0.393	58.3
Electric Equipment	75,036	0.244	36.1
Misc. Electric	0	0.000	0.0
Misc. Fuel Use	0	0.000	0.0
Non-HVAC Sub-Total	**196,158**	**0.637**	**94.4**
Grand Total	**207,800**	**0.675**	**100.0**

Note: Cost per unit floor area is based on the gross building floor area.

Note much of the tenant fit out has not been included in this cost estimate. The additions made by the tenants are expected to add a large energy and heating load to the base estimates here. The additional loads will be handled by Air Handling Units 3 and 4 which are currently serving only the water closets throughout the building.

The Palestra Building's operating cost is roughly £200,000 which seems quite low for a 37,000 square meter building. However, again these numbers will increase with the additional loads and operation of all the chillers.

X. Conclusion

This report took a closer look at the mechanical structures of the Palestra Building looking at the design's environmental consciousness according to the LEED program, power consumption densities according to ASHRAE Standard 90, lost rentable space due to mechanical systems, fuel utilization data, emissions, and load and energy analysis. All of these issues will then be computed with respect to money, the bottom line for most projects, and compared for its efficiency with similar projects of scope and size.

The Palestra Building received 42% of the points (29 of 69 points) according to LEED. With 29 points the Palestra Building is certified as a LEED building, but it does not qualify for the Silver, Gold, or Platinum certifications.

The envelope was found to be compliant with ASHRAE Standard 90.1. The Palestra Building was found to have 44.3% glazing on its façade which is less than the 50% maximum as stated in Standard 90. The façade's shading coefficients for the South/East/West elevations on the Ground-8 floors also did not comply with a value of 0.34 > 0.25 as stated in the Standard. Therefore, Palestra does not meet the ASHRAE glazing requirements.

The lighting consumption of Palestra was also calculated according to ASHRAE Standard 90. Following the 'Space by Space' method outlined in the Standard, only four of the six typical spaces sorted by activity passed. This included the water closets, reception area, plant room, and corridors. The spaces that did not pass were the Office Space (15.75 W/m^2 > 11.83 W/m^2) and below grade Car Park (3.5W/m^2 > 2.15W/m^2). From the design documents it is known that 15 W/m^2 for lighting in office areas was considered to be 'Good Practice' according to CIBSE guides. Therefore, while the design approximately meets the design intent in the UK, it exceeds the maximum values in the US. The 'Building Area Method' confirms this assumption where the overall power density for this office building was found to be 14.7 W/m^2 versus the 10.7 W/m^2 suggested by ASHRAE for an office building.

The Palestra Building was found to have 10.56% of the Gross Internal Area reserved for mechanical systems and spaces. While 10% of the rentable space seems large, the design team went to great lengths to centralize the systems and streamline the cores in order to minimize this value. As stated before they were aiming to achieve a val;ue between 6 and 11%. Due to the fact that the Palestra Building is fully mechanically ventilated, which is unusual in London's moderate climate, it seems appropriate that it is at the higher end of that range.

The Palestra Building is predicted to have a £200,000 annual operating cost according to the HAP analysis, with a capital cost of £9.9 million for the mechanical systems. However, please note that the Natural Gas price from British Gas of 5.9 pence/kWh does not appear to have been utilized in this HAP analysis. This is most likely due to a linking error in system design within HAP, however this error could not be located. The actual annual operating costs are expected to be much greater for several reasons in addition to the £65,000 natural gas cost per annum. This analysis only accounts for three of the seven air handling units. While the three here account for 86% of the building's floor area, the additional units will increase the operating costs. Brining more air handling units online will also increase the chiller loads which will also affect the costs.

Calculating the electrical generations according to the UK mix of Coal: 34%, Oil: 2%, Natural Gas: 37%, Nuclear: 23%, Hydro/Wind: 4% the Palestra Building was found to have a fairly significant impact on its surroundings. With 34900 lbm of SOx, 16400 lbm of CO2, and 7240000 lbm of NOx the building could take a second look at some emission efficient equipment that could reduce these values. If this design had fallen under the new 2005 Part L Energy Regulations in the UK, they would have to decrease the CO2 emissions by 28% (4952 lbm) which is a significant amount of pollutant.

Palestra was clearly designed with the emphasis on its iconic façade and design. Therefore it is interesting to see how the mechanical side of the design performs and impacts the environment due to the owners desire to keep capital costs low and running costs lower.

XI. References

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APPENDIX A

Ground Level			
Element	Area (m²)	Actual U-Value (W/m²K)	Rate of heat loss per degree (W/K)
Exposed Walls	0	0.2	0
Semi – exposed walls and floors	193	0.2	38.6
Glazed Curtain Wall	323	2.1	678.5
Windows	0	3.3	0.0
Roof	0	0.2	0.0
Floor	0	0.2	0.0
Rooflights	0	2.6	0.0
Totals	516		**717.10**

Level 1			
Element	Area (m²)	Actual U-Value (W/m²K)	Rate of heat loss per degree (W/K)
Exposed walls	0	0.2	0
Glazed Curtain Wall	564	2.1	1183.8
Windows	0	3.3	0.0
Roof	0	0.2	0.0
Floor	0	0.2	0.0
Rooflights	0	2.6	0.0
Totals	564		**1183.81**

Level 2			
Element	Area (m²)	Actual U-Value (W/m²K)	Rate of heat loss per degree (W/K)
Exposed Walls	0	0.2	0
Semi – exposed walls amd floors	0	0.2	0
Glazed Curtain Wall	915	2.1	1922.4
Windows	0	3.3	0.0
Roof	0	0.2	0.0
Floor	328	0.2	65.6
Rooflights	0	2.6	0.0
Totals	1244		**1988**

Levels 3-5			
	Area	Actual U-Value	Rate of heat loss per degree
Element	(m^2)	(W/m^2K)	(W/K)
Wall Type 1	0	0.2	0
Wall Type 2	0	0.2	0
Glazed Curtain Wall	2746	2.1	5767.1
Windows	0	3.3	0.0
Roof	0	0.2	0.0
Floor	0	0.2	0.0
Rooflights	0	2.6	0.0
Totals	2746		**5767.15**

Level 6			
	Area	Actual U-Value	Rate of heat loss per degree
Element	(m^2)	(W/m^2K)	(W/K)
Wall Type 1	0	0.2	0
Wall Type 2	0	0.2	0
Glazed Curtain Wall	915	2.1	1922.4
Windows	0	3.3	0.0
Roof	562	0.2	112.4
Floor	0	0.2	0.0
Rooflights	0	2.6	0.0
Totals	1477		**2034.8**

Level 7			
	Area	Actual U-Value	Rate of heat loss per degree
Element	(m^2)	(W/m^2K)	(W/K)
Wall Type 1	0	0.2	0
Wall Type 2	0	0.2	0
Glazed Curtain Wall	921	2.1	1934.6
Windows	0	3.3	0.0
Roof	284	0.2	56.8
Floor	0	0.2	0.0
Rooflights	0	2.6	0.0
Totals	1205		**1991.4**

Level 8			
Element	Area (m²)	Actual U-Value (W/m²K)	Rate of heat loss per degree (W/K)
Wall Type 1	0	0.2	0
Glazed Curtain Wall	819	2.1	1720.0
Windows	0	3.3	0.0
Roof	0	0.2	0.0
Floor	0	0.2	0.0
Rooflights	0	2.6	0.0
Totals	819		**1720.03**

Level 9			
Element	Area (m²)	Actual U-Value (W/m²K)	Rate of heat loss per degree (W/K)
Wall Type 1	0	0.2	0
Wall Type 2	0	0.2	0
Glazed Curtain Wall	907	2.1	1903.9
Windows	0	3.3	0.0
Roof	0	0.2	0.0
Floor	238	0.2	47.6
Rooflights	0	2.6	0.0
Totals	1145		**1951.5**

Level 10			
Element	Area (m²)	Actual U-Value (W/m²K)	Rate of heat loss per degree (W/K)
Wall Type 1	0	0.2	0
Wall Type 2	0	0.6	0
Glazed Curtain Wall	2720	2.1	5712.0
Windows	0	3.3	0.0
Roof	0	0.45	0.0
Floor	0	0.45	0.0
Rooflights	0	2.6	0.0
Totals	2720		**5712.00**

Level 11			
	Area	Actual U-Value	Rate of heat loss per degree
Element	(m^2)	(W/m^2K)	(W/K)
Wall Type 1	0	0.2	0
Wall Type 2	0	0.2	0
Glazed Curtain Wall	2720	2.1	5712.0
Windows	0	3.3	0.0
Roof	2676	0.2	535.2
Floor	0	0.2	0.0
Rooflights	0	2.6	0.0
Totals	5396		**6247.2**

Appendix B

Fabric Heating Load				
Total Fabric insulation (from Appendix H)	17014	W/K		
External temperature	-3	deg.C		
Internal temperature (Assume identical throughout)	22	deg.C		
Total Fabric load	**425351**	W		

Infiltration Heating Load				
Total Façade area	10800	m^2		
Infiltration rate	2.5	m^3/hr/m2		
temperature difference (as above)	25	K	Indexes	
Volume of infiltration	7.5	m^3/s	Building Floor height	3.6
Thermal capacity of air	1200	J/m3.K	Air changes per hour	0.23
Total Infiltration load	**225000**	**W**		

Mechanical Ventilation Heating Load		
Total floor area	26677	m^2
Occupancy	12	m^2/occupant
Ventilation Flow rate	16	l/s/occupant
Air tempered to	22	deg.C
External air	-3	deg.C
Thermal Efficiency of ventilation plant	50	%
Temperature difference	12.5	K
Ventilation Flow rate	35.6	m^3/s
Air thermal Capacity	1200.0	J/m^3.K
System losses	10%	
Ventilation heat load	586894	W

Total Heating Load				
Total Heating Load	**1,237**	**kW**	Indexes	
Spare capacity	10%			
Pre-heat period	32%		Building Floor area	26677
Installed Heating Load	**1,796**	**kW**	Load per m2 (W/m^2)	67.3

Breakdown of cooling loads

Internal Cooling Load	**BH proposed Brief**	
persons	10 W/m2	m^2/occupant
light	15 W/m2	W/m^2

equip	30 W/m2	W/m^2
Fan Coil units	6 W/m2	W/m^2
total - Internal	**61 W/m2**	W/m^2
Environmental Cooling Load		
Room Temperature	22	deg.C
Outdoor temperature	29	deg.C
Difference	7	deg.C
Solar cooling load	25	W/m^2 (estimate) *
Fabric cooling load	5	W/m^2 (estimate) *
Infiltration cooling load	1.9	W/m^2 (estimate) *
Total Environmental	**32 W/m2**	
Mechanical Ventilation Cooling Load		
Total floor area	26677	m^2
Occupancy	12	m^2/occupant
Ventilation Flow rate	16	l/s/occupant
Air tempered to	22	deg.C
External air	29	deg.C
Thermal Efficiency of ventilation plant	50	% (estimate) *
Temperature difference	-3.5	K
Ventilation Flow rate	35.6	m^3/s
Air thermal Capacity	1200.0	$J/m^3.K$
Ventilation cooling load	149391	W (estimate) *
Ventilation cooling load	5.6	W/m^2 (estimate) *
Total		
total W/m2	99	W/m^2
Area	26416	m^2
Total Cooling Load	2602	W
Sensible Heat Ratio	15%	
System Losses	10%	
Total	**3,291 kW**	

Proposed chillers	Capacity	Spare
6 x 0.553 MW	**3,318 kW**	**0.81%**
7 x 0.553 MW	**3,871 kW**	**17.61%**

Appendix C – HAP Results

Air System Information

Air System Name	**AHU-1**		Number of zones	**12**	
Equipment Class	**CW AHU**		Floor Area	**149886.8**	ft²
Air System Type	**VAV**		Location	**London - Heathrow, United Kingdom**	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	**Peak zone sensible load**		Calculation Months	**Jan to Dec**	
Space CFM	**Individual peak space loads**		Sizing Data	**Calculated**	

Central Cooling Coil Sizing Data

Total coil load	**136.1**	Tons	Load occurs at	**Aug 1400**	
Total coil load	**1633.1**	MBH	OA DB / WB	**80.5 / 65.8**	°F
Sensible coil load	**1633.1**	MBH	Entering DB / WB	**79.9 / 65.7**	°F
Coil CFM at Aug 1400	**82278**	CFM	Leaving DB / WB	**61.5 / 59.3**	°F
Max block CFM at Aug 1400	**107034**	CFM	Coil ADP	**59.4**	°F
Sum of peak zone CFM	**107265**	CFM	Bypass Factor	**0.100**	
Sensible heat ratio	**1.000**		Resulting RH	**53**	%
ft²/Ton	**1101.4**		Design supply temp.	**61.7**	°F
BTU/(hr-ft²)	**10.9**		Zone T-stat Check	**12 of 12**	OK
Water flow @ 10.0 °F rise	**326.79**	gpm	Max zone temperature deviation	**0.0**	°F

Supply Fan Sizing Data

Actual max CFM at Aug 1400	**107034**	CFM	Fan motor BHP	**10.00**	BHP
Standard CFM	**106733**	CFM	Fan motor kW	**7.46**	kW
Actual max CFM/ft²	**0.71**	CFM/ft²			

Outdoor Ventilation Air Data

Design airflow CFM	**67512**	CFM	CFM/person	**152.05**	CFM/person
CFM/ft²	**0.45**	CFM/ft²			

Air System Design Load Summary for AHU-1

Project Name: Palestra2 10/31/2005
Prepared by: psuae 12:35AM

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Aug 1400 COOLING OA DB / WB 80.5 °F / 65.8 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 25.0 °F / 21.0 °F		
ZONE LOADS	**Details**	**Sensible (BTU/hr)**	**Latent (BTU/hr)**	**Details**	**Sensible (BTU/hr)**	**Latent (BTU/hr)**
Window & Skylight Solar Loads	29255 ft²	298809	-	29255 ft²	-	-
Wall Transmission	31536 ft²	43889	-	31536 ft²	86610	-
Roof Transmission	14359 ft²	30990	-	14359 ft²	28113	-
Window Transmission	29255 ft²	24754	-	29255 ft²	447602	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	5267 ft²	0	-	5267 ft²	0	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	149887 ft²	0	-	149887 ft²	0	-
Overhead Lighting	225010 W	618123	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	139395 W	434250	-	0	0	-
People	444	82290	91020	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	**-**	**1533105**	**91020**	**-**	**562325**	**0**
Zone Conditioning	-	1371550	91020	-	368759	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	82278 CFM	0	-	1073 CFM	0	-
Ventilation Load	67512 CFM	241638	-91020	1073 CFM	49460	0
Supply Fan Load	82278 CFM	19893	-	1073 CFM	-5496	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
>> Total System Loads	**-**	**1633081**	**0**	**-**	**412723**	**0**
Central Cooling Coil	-	1633082	0	-	0	0
Terminal Reheat Coils	-	0	-	-	0	-
Zone Heating Unit Coils	-	0	-	-	412723	-
>> Total Conditioning	**-**	**1633082**	**0**	**-**	**412723**	**0**
Key:	**Positive values are clg loads Negative values are htg loads**			**Positive values are htg loads Negative values are clg loads**		

Air System Sizing Summary for AHU-2

Air System Information

Air System Name	**AHU-2**		Number of zones	**12**	
Equipment Class	**CW AHU**		Floor Area	**149886.8**	ft²
Air System Type	**VAV**		Location	**London - Heathrow, United Kingdom**	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	**Peak zone sensible load**	Calculation Months	**Jan to Dec**
Space CFM	**Individual peak space loads**	Sizing Data	**Calculated**

Central Cooling Coil Sizing Data

Total coil load	**135.4**	Tons	Load occurs at	**Jul 1400**	
Total coil load	**1624.8**	MBH	OA DB / WB	**80.5 / 65.8**	°F
Sensible coil load	**1624.8**	MBH	Entering DB / WB	**79.9 / 65.7**	°F
Coil CFM at Jul 1400	**81776**	CFM	Leaving DB / WB	**61.5 / 59.3**	°F
Max block CFM at Aug 1400	**106214**	CFM	Coil ADP	**59.4**	°F
Sum of peak zone CFM	**106445**	CFM	Bypass Factor	**0.100**	
Sensible heat ratio	**1.000**		Resulting RH	**53**	%
ft²/Ton	**1107.0**		Design supply temp.	**61.7**	°F
BTU/(hr-ft²)	**10.8**		Zone T-stat Check	**12 of 12**	OK
Water flow @ 10.0 °F rise	**325.13**	gpm	Max zone temperature deviation	**0.0**	°F

Supply Fan Sizing Data

Actual max CFM at Aug 1400	**106214**	CFM	Fan motor BHP	**10.00**	BHP
Standard CFM	**105915**	CFM	Fan motor kW	**7.46**	kW
Actual max CFM/ft²	**0.71**	CFM/ft²			

Outdoor Ventilation Air Data

Design airflow CFM	**67512**	CFM	CFM/person	**152.05**	CFM/person
CFM/ft²	**0.45**	CFM/ft²			

Air System Design Load Summary for AHU-2

Project Name: Palestra2 10/31/2005
Prepared by: psuae 12:36AM

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Jul 1400 COOLING OA DB / WB 80.5 °F / 65.8 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 25.0 °F / 21.0 °F		
ZONE LOADS	**Details**	**Sensible (BTU/hr)**	**Latent (BTU/hr)**	**Details**	**Sensible (BTU/hr)**	**Latent (BTU/hr)**
Window & Skylight Solar Loads	29255 ft²	280776	-	29255 ft²	-	-
Wall Transmission	31536 ft²	38991	-	31536 ft²	86610	-
Roof Transmission	14359 ft²	35740	-	14359 ft²	28113	-
Window Transmission	29255 ft²	24754	-	29255 ft²	447602	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	5267 ft²	0	-	5267 ft²	0	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	149887 ft²	0	-	149887 ft²	0	-
Overhead Lighting	225010 W	618123	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	139395 W	434250	-	0	0	-
People	444	82290	91020	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	**-**	**1514924**	**91020**	**-**	**562325**	**0**
Zone Conditioning	-	1363529	91020	-	368882	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	81776 CFM	0	-	1064 CFM	0	-
Ventilation Load	67512 CFM	241354	-91020	1064 CFM	49083	0
Supply Fan Load	81776 CFM	19921	-	1064 CFM	-5496	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
>> Total System Loads	**-**	**1624804**	**0**	**-**	**412470**	**0**
Central Cooling Coil	-	1624803	0	-	0	0
Terminal Reheat Coils	-	0	-	-	0	-
Zone Heating Unit Coils	-	0	-	-	412470	-
>> Total Conditioning	**-**	**1624803**	**0**	**-**	**412470**	**0**
Key:	**Positive values are clg loads Negative values are htg loads**			**Positive values are htg loads Negative values are clg loads**		

Air System Sizing Summary for AHU-7

Air System Information

Air System Name	AHU-7		Number of zones	1	
Equipment Class	CW AHU		Floor Area	8306.7	ft²
Air System Type	VAV		Location	London - Heathrow, United Kingdom	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	Peak zone sensible load	Calculation Months	Jan to Dec
Space CFM	Individual peak space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data

Total coil load	11.3	Tons	Load occurs at	Aug 1400	
Total coil load	135.2	MBH	OA DB / WB	80.5 / 65.8	°F
Sensible coil load	116.4	MBH	Entering DB / WB	80.1 / 65.6	°F
Coil CFM at Aug 1400	4814	CFM	Leaving DB / WB	57.6 / 56.3	°F
Max block CFM at Sep 1400	5859	CFM	Coil ADP	55.1	°F
Sum of peak zone CFM	5859	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.861		Resulting RH	48	%
ft²/Ton	737.3		Design supply temp.	61.7	°F
BTU/(hr-ft²)	16.3		Zone T-stat Check	1 of 1	OK
Water flow @ 10.0 °F rise	27.06	gpm	Max zone temperature deviation	0.0	°F

Supply Fan Sizing Data

Actual max CFM at Sep 1400	5859	CFM	Fan motor BHP	10.00	BHP
Standard CFM	5843	CFM	Fan motor kW	7.46	kW
Actual max CFM/ft²	0.71	CFM/ft²			

Outdoor Ventilation Air Data

Design airflow CFM	4162	CFM	CFM/person	112.48	CFM/person
CFM/ft²	0.50	CFM/ft²			

Air System Design Load Summary for AHU-7

Project Name: Palestra2 | 10/31/2005
Prepared by: psuae | 12:37AM

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Aug 1400 COOLING OA DB / WB 80.5 °F / 65.8 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 25.0 °F / 21.0 °F		
ZONE LOADS	**Details**	**Sensible (BTU/hr)**	**Latent (BTU/hr)**	**Details**	**Sensible (BTU/hr)**	**Latent (BTU/hr)**
Window & Skylight Solar Loads	502 ft²	8657	-	502 ft²	-	-
Wall Transmission	3307 ft²	7632	-	3307 ft²	9082	-
Roof Transmission	0 ft²	0	-	0 ft²	0	-
Window Transmission	502 ft²	425	-	502 ft²	7684	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	3809 ft²	0	-	3809 ft²	0	-
Partitions	0 ft²	0	-	0 ft²	0	-
Ceiling	3809 ft²	0	-	3809 ft²	0	-
Overhead Lighting	12470 W	34256	-	0	0	-
Task Lighting	0 W	0	-	0	0	-
Electric Equipment	7725 W	24066	-	0	0	-
People	37	6858	7585	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	**-**	**81895**	**7585**	**-**	**16765**	**0**
Zone Conditioning	-	81199	7585	-	11276	0
Plenum Wall Load	0%	0	-	0	0	-
Plenum Roof Load	0%	0	-	0	0	-
Plenum Lighting Load	0%	0	-	0	0	-
Return Fan Load	4814 CFM	0	-	59 CFM	0	-
Ventilation Load	4162 CFM	14068	11193	59 CFM	2708	-307
Supply Fan Load	4814 CFM	21158	-	59 CFM	-5496	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	0%	0	-	0%	0	-
>> Total System Loads	**-**	**116425**	**18778**	**-**	**8488**	**-307**
Central Cooling Coil	-	116425	18778	-	-3180	-307
Terminal Reheat Coils	-	0	-	-	0	-
Zone Heating Unit Coils	-	0	-	-	11668	-
>> Total Conditioning	**-**	**116425**	**18778**	**-**	**8488**	**-307**
Key:	**Positive values are clg loads Negative values are htg loads**			**Positive values are htg loads Negative values are clg loads**		

Cooling Plant Sizing Summary for Palestra

1. Plant Information:

Plant Name .... **Palestra**
Plant Type .... **Chiller Plant**
Design Weather .... **London - Heathrow, United Kingdom**

2. Cooling Plant Sizing Data:

Maximum Plant Load .... **282.7** Tons
Load occurs at .... **Aug 1400**
ft²/Ton .... **1089.8** ft²/Ton
Floor area served by plant .... **308080.3** ft²

3. Coincident Air System Cooling Loads for Aug 1400

Air System Name	Mult.	System Cooling Coil Load (Tons)
AHU-1	1	136.1
AHU-2	1	135.3
AHU-7	1	11.3

System loads are for coils whose cooling source is ' Chilled Water ' .

Unmet Load Report for Palestra

Palestra2 10/31/2005
psuae 12:40AM

1. Unmet Load Statistics

Month	Equipment Capacity is Sufficient (hrs)	Capacity Insufficient by 0%-5% (hrs)	Capacity Insufficient by 5%-10% (hrs)	Capacity Insufficient by >10% (hrs)	Total Hours with Unmet Loads	Total Hours with Equipment Loads
January	30	0	0	0	0	30
February	29	0	0	0	0	29
March	16	0	0	0	0	16
April	95	0	0	0	0	95
May	198	0	0	0	0	198
June	263	0	0	0	0	263
July	294	0	0	0	0	294
August	317	0	0	0	0	317
September	310	0	0	0	0	310
October	194	0	0	0	0	194
November	50	0	0	0	0	50
December	47	0	0	0	0	47
Total	**1843**	**0**	**0**	**0**	**0**	**1843**

Table 1. Annual Costs

Component	Palestra (£)
Air System Fans	2,649
Cooling	6,513
Heating	0
Pumps	0
Cooling Tower Fans	2,480
HVAC Sub-Total	**11,642**
Lights	121,122
Electric Equipment	75,036
Misc. Electric	0
Misc. Fuel Use	0
Non-HVAC Sub-Total	**196,158**
Grand Total	**207,800**

Table 2. Annual Cost per Unit Floor Area

Component	Palestra (£/ft²)
Air System Fans	0.009
Cooling	0.021
Heating	0.000
Pumps	0.000
Cooling Tower Fans	0.008
HVAC Sub-Total	**0.038**
Lights	0.393
Electric Equipment	0.244
Misc. Electric	0.000
Misc. Fuel Use	0.000
Non-HVAC Sub-Total	**0.637**
Grand Total	**0.675**
Gross Floor Area (ft²)	308080.3
Conditioned Floor Area (ft²)	308080.3

Note: Values in this table are calculated using the Gross Floor Area.

Table 3. Component Cost as a Percentage of Total Cost

Component	Palestra (%)
Air System Fans	1.3
Cooling	3.1
Heating	0.0
Pumps	0.0
Cooling Tower Fans	1.2
HVAC Sub-Total	**5.6**
Lights	58.3
Electric Equipment	36.1
Misc. Electric	0.0
Misc. Fuel Use	0.0
Non-HVAC Sub-Total	**94.4**
Grand Total	**100.0**

Annual Energy and Emissions Summary

Table 1. Annual Costs

Component	Palestra (£)
HVAC Components	
Electric	11,642
Natural Gas	0
Fuel Oil	0
Propane	0
Remote HW	0
Remote Steam	0
Remote CW	0
HVAC Sub-Total	**11,642**
Non-HVAC Components	
Electric	196,160
Natural Gas	0
Fuel Oil	0
Propane	0
Remote HW	0
Remote Steam	0
Non-HVAC Sub-Total	**196,160**
Grand Total	**207,802**

Table 2. Annual Energy Consumption

Component	Palestra
HVAC Components	
Electric (kWh)	149,670
Natural Gas (na)	0
Fuel Oil ()	1,246
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Remote CW (na)	0
Non-HVAC Components	
Electric (kWh)	2,521,820
Natural Gas (na)	0
Fuel Oil ()	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Totals	
Electric (kWh)	2,671,489
Natural Gas (na)	0
Fuel Oil ()	1,246
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Remote CW (na)	0

Table 3. Annual Emissions

Component	Palestra
CO2 (lb)	0
SO2 (kg)	0
NOx (kg)	0

Table 4. Annual Cost per Unit Floor Area

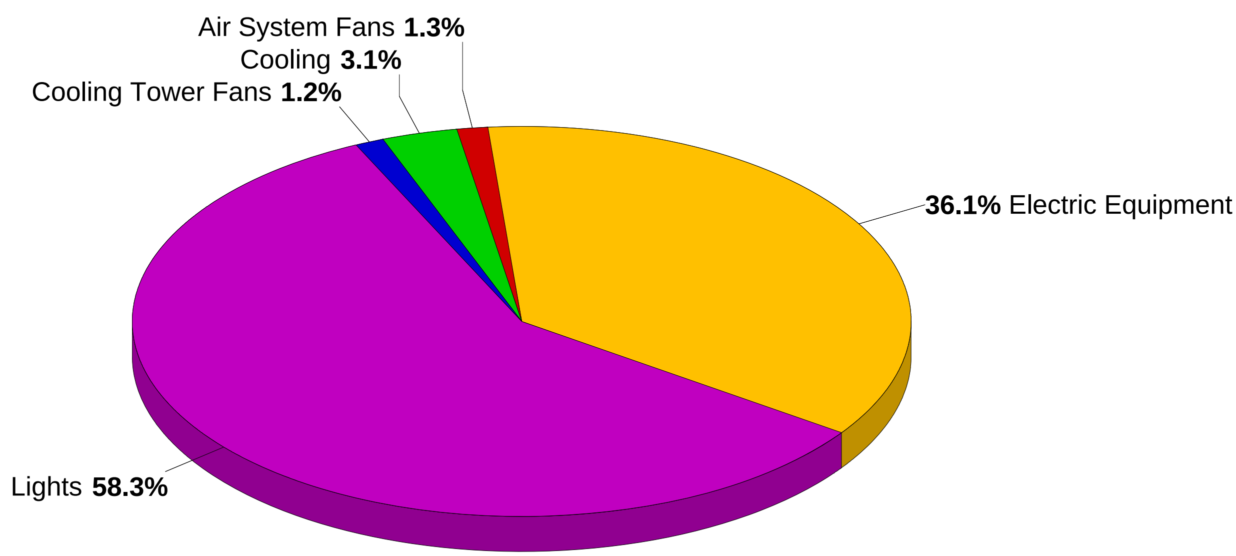
Component	Palestra (£/ft²)
HVAC Components	
Electric	0.038
Natural Gas	0.000
Fuel Oil	0.000
Propane	0.000
Remote HW	0.000
Remote Steam	0.000
Remote CW	0.000
HVAC Sub-Total	**0.038**
Non-HVAC Components	
Electric	0.637
Natural Gas	0.000
Fuel Oil	0.000
Propane	0.000
Remote HW	0.000
Remote Steam	0.000
Non-HVAC Sub-Total	**0.637**
Grand Total	**0.675**
Gross Floor Area (ft²)	308080.3
Conditioned Floor Area (ft²)	308080.3

Note: Values in this table are calculated using the Gross Floor Area.

Table 5. Component Cost as a Percentage of Total Cost

Component	Palestra (%)
HVAC Components	
Electric	5.6
Natural Gas	0.0
Fuel Oil	0.0
Propane	0.0
Remote HW	0.0
Remote Steam	0.0
Remote CW	0.0
HVAC Sub-Total	**5.6**
Non-HVAC Components	
Electric	94.4
Natural Gas	0.0
Fuel Oil	0.0
Propane	0.0
Remote HW	0.0
Remote Steam	0.0
Non-HVAC Sub-Total	**94.4**
Grand Total	**100.0**

Annual Component Costs - Palestra



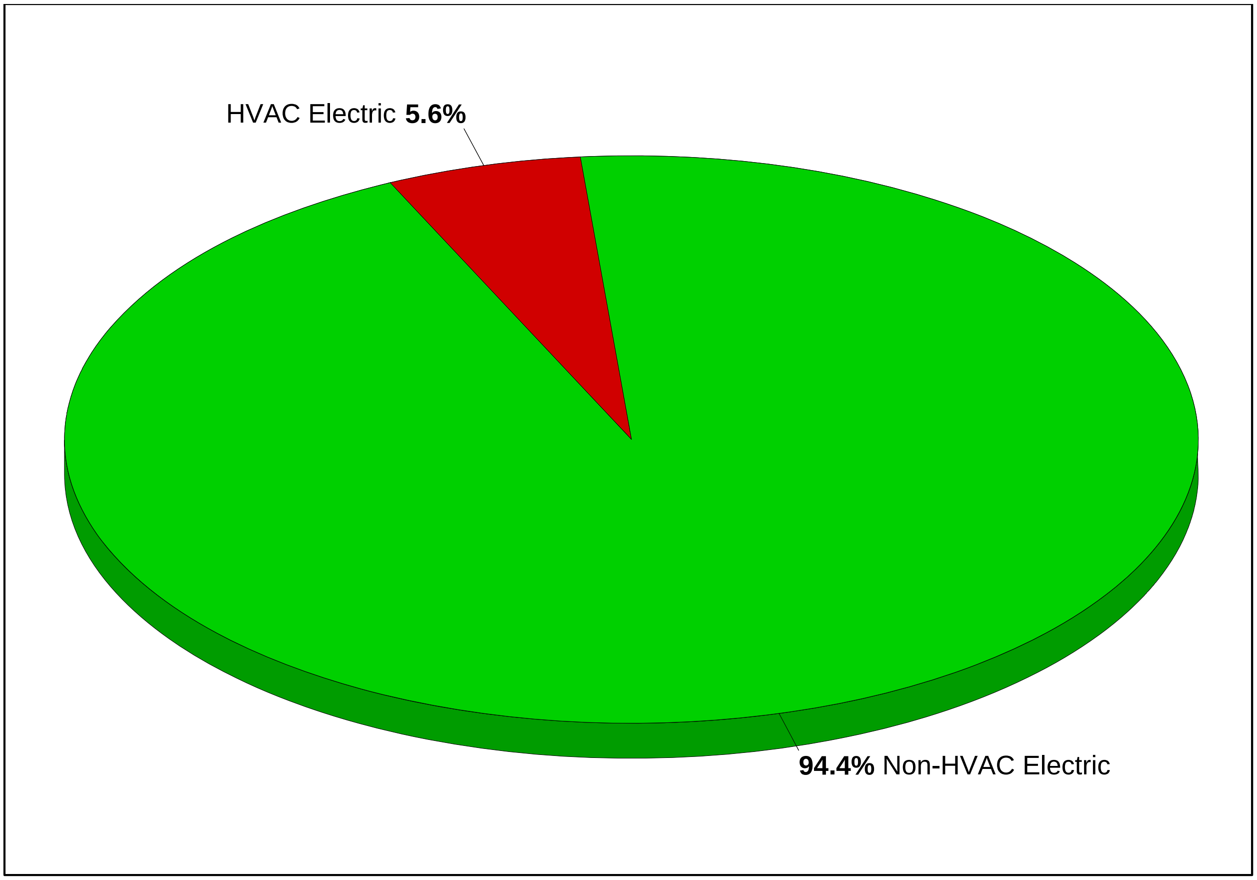
1. Annual Costs

Component	Annual Cost (£)	(£/ft²)	Percent of Total (%)
Air System Fans	2,649	0.009	1.3
Cooling	6,513	0.021	3.1
Heating	0	0.000	0.0
Pumps	0	0.000	0.0
Cooling Tower Fans	2,480	0.008	1.2
HVAC Sub-Total	**11,642**	**0.038**	**5.6**
Lights	121,122	0.393	58.3
Electric Equipment	75,036	0.244	36.1
Misc. Electric	0	0.000	0.0
Misc. Fuel Use	0	0.000	0.0
Non-HVAC Sub-Total	**196,158**	**0.637**	**94.4**
Grand Total	**207,800**	**0.675**	**100.0**

Note: Cost per unit floor area is based on the gross building floor area.

Gross Floor Area .... **308080.3** ft²
Conditioned Floor Area .... **308080.3** ft²

Annual Energy Costs - Palestra



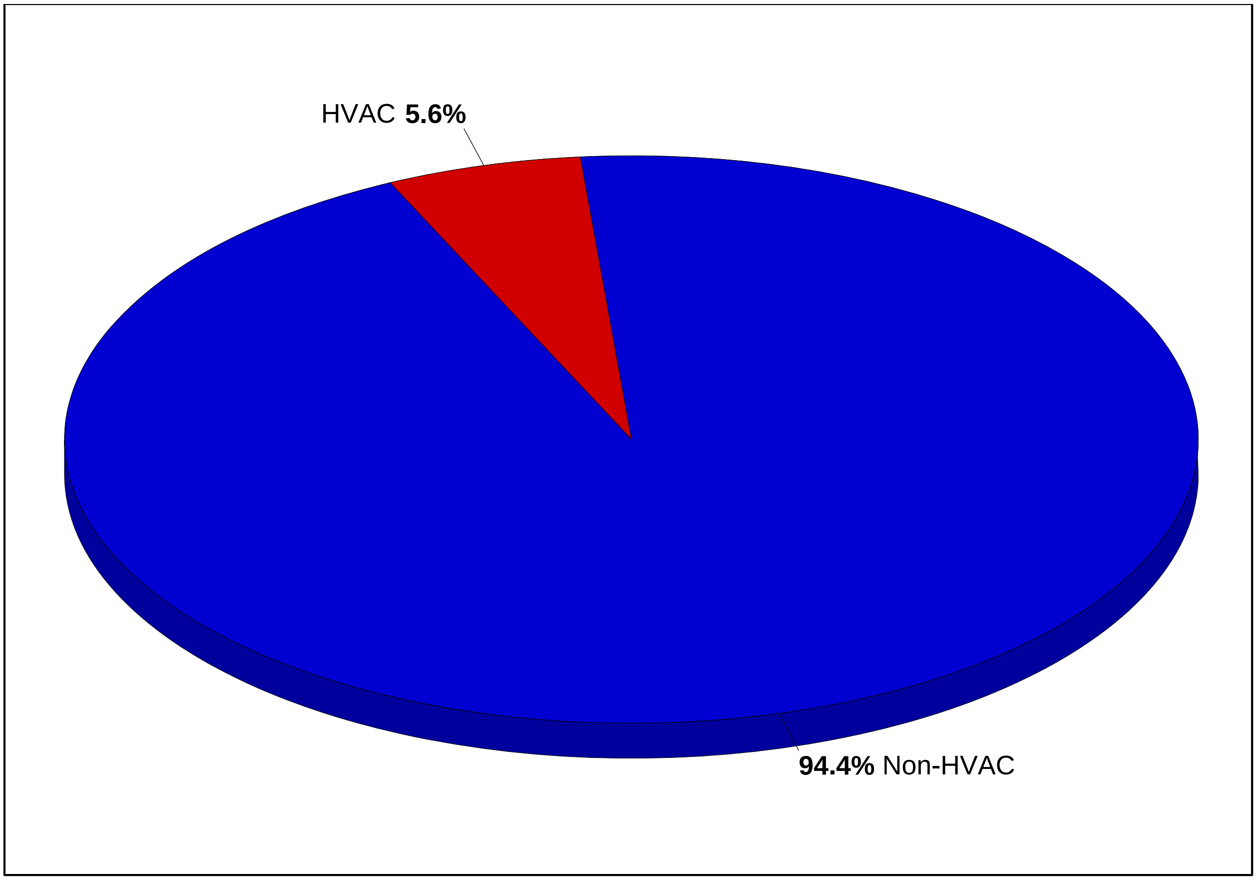
1. Annual Costs

Component	Annual Cost (£/yr)	(£/ft²)	Percent of Total (%)
HVAC Components			
Electric	11,642	0.038	5.6
Natural Gas	0	0.000	0.0
Fuel Oil	0	0.000	0.0
Propane	0	0.000	0.0
Remote Hot Water	0	0.000	0.0
Remote Steam	0	0.000	0.0
Remote Chilled Water	0	0.000	0.0
HVAC Sub-Total	**11,642**	**0.038**	**5.6**
Non-HVAC Components			
Electric	196,160	0.637	94.4
Natural Gas	0	0.000	0.0
Fuel Oil	0	0.000	0.0
Propane	0	0.000	0.0
Remote Hot Water	0	0.000	0.0
Remote Steam	0	0.000	0.0
Non-HVAC Sub-Total	**196,160**	**0.637**	**94.4**
Grand Total	**207,802**	**0.675**	**100.0**

Note: Cost per unit floor area is based on the gross building floor area.

Gross Floor Area .... **308080.3** ft²
Conditioned Floor Area .... **308080.3** ft²

Annual HVAC & Non-HVAC Cost Totals - Palestra



1. Annual Costs

Component	Annual Cost (£/yr)	(£/ft²)	Percent of Total (%)
HVAC	11,642	0.038	5.6
Non-HVAC	196,158	0.637	94.4
Grand Total	**207,800**	**0.675**	**100.0**

Note: Cost per unit floor area is based on the gross building floor area.

Gross Floor Area .... **308080.3** ft²
Conditioned Floor Area .... **308080.3** ft²

Energy Budget by System Component - Palestra

1. Annual Coil Loads

Component	Load (kBTU)	(kBTU/ft²)
Cooling Coil Loads	900,005	2.921
Heating Coil Loads	858	0.003
Grand Total	**900,863**	**2.924**

2. Energy Consumption by System Component

Component	Site Energy (kBTU)	Site Energy (kBTU/ft²)	Source Energy (kBTU)	Source Energy (kBTU/ft²)
Air System Fans	116,212	0.377	415,044	1.347
Cooling	285,675	0.927	1,020,268	3.312
Heating	1,246	0.004	1,246	0.004
Pumps	0	0.000	0	0.000
Cooling Towers	108,786	0.353	388,521	1.261
HVAC Sub-Total	**511,919**	**1.662**	**1,825,078**	**5.924**
Lights	5,312,958	17.245	18,974,848	61.591
Electric Equipment	3,291,426	10.684	11,755,093	38.156
Misc. Electric	0	0.000	0	0.000
Misc. Fuel Use	0	0.000	0	0.000
Non-HVAC Sub-Total	**8,604,383**	**27.929**	**30,729,941**	**99.747**
Grand Total	**9,116,302**	**29.591**	**32,555,019**	**105.671**

Notes:

1. 'Cooling Coil Loads' is the sum of all air system cooling coil loads.
2. 'Heating Coil Loads' is the sum of all air system heating coil loads.
3. Site Energy is the actual energy consumed.
4. Source Energy is the site energy divided by the electric generating efficiency (28.0%).
5. Source Energy for fuels equals the site energy value.
6. Energy per unit floor area is based on the gross building floor area.
   Gross Floor Area .... **308080.3** ft²
   Conditioned Floor Area .... **308080.3** ft²

Energy Budget by Energy Source - Palestra

1. Annual Coil Loads

Component	Load (kBTU)	(kBTU/ft²)
Cooling Coil Loads	900,005	2.921
Heating Coil Loads	858	0.003
Grand Total	**900,863**	**2.924**

2. Energy Consumption by Energy Source

Component	Site Energy (kBTU)	Site Energy (kBTU/ft²)	Source Energy (kBTU)	Source Energy (kBTU/ft²)
HVAC Components				
Electric	510,673	1.658	1,823,832	5.920
Natural Gas	0	0.000	0	0.000
Fuel Oil	1,246	0.004	1,246	0.004
Propane	0	0.000	0	0.000
Remote Hot Water	0	0.000	0	0.000
Remote Steam	0	0.000	0	0.000
Remote Chilled Water	0	0.000	0	0.000
HVAC Sub-Total	**511,919**	**1.662**	**1,825,078**	**5.924**
Non-HVAC Components				
Electric	8,604,448	27.929	30,730,172	99.747
Natural Gas	0	0.000	0	0.000
Fuel Oil	0	0.000	0	0.000
Propane	0	0.000	0	0.000
Remote Hot Water	0	0.000	0	0.000
Remote Steam	0	0.000	0	0.000
Non-HVAC Sub-Total	**8,604,448**	**27.929**	**30,730,172**	**99.747**
Grand Total	**9,116,367**	**29.591**	**32,555,250**	**105.671**

Notes:
1. 'Cooling Coil Loads' is the sum of all air system cooling coil loads.
2. 'Heating Coil Loads' is the sum of all air system heating coil loads.
3. Site Energy is the actual energy consumed.
4. Source Energy is the site energy divided by the electric generating efficiency (28.0%).
5. Source Energy for fuels equals the site energy value.
6. Energy per unit floor area is based on the gross building floor area.
   Gross Floor Area .... **308080.3** ft²
   Conditioned Floor Area .... **308080.3** ft²