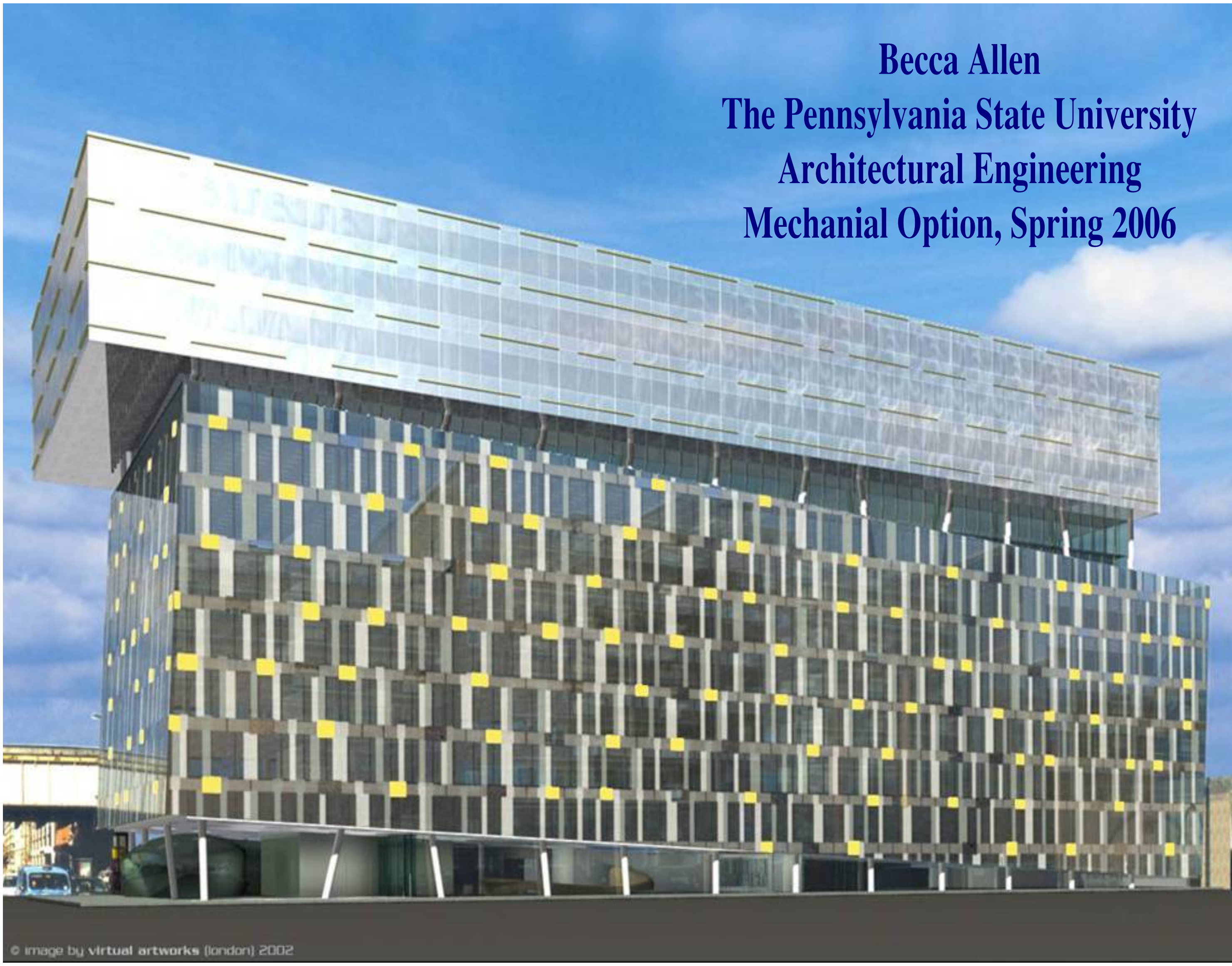
PENNSTATE

Optimizing Energy Efficiency of the Palestra Building

London, England

Becca Allen
The Pennsylvania State University
Architectural Engineering
Mechanial Option, Spring 2006



Architectural Renderings compliments of Alsop Architects

SKANSKA

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Buro Happold

The Palestra Building

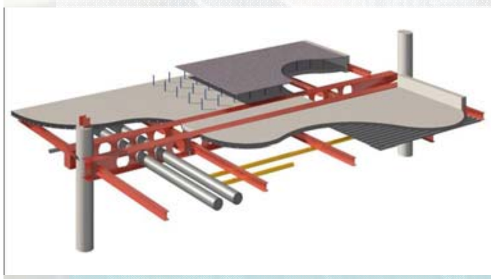
London, England ~ Rebecca Allen, Mechanical Option

Architecture

- Size: 37,098 m^2
- Floors: 12
- Cost: £68 million
- Features:
  - ‘Dancing’ Columns
  - 3-9m cantilevers
  - 11 degree slant on façade
  - Floating Box Effect
- Completion Date: June 2006

Project Team

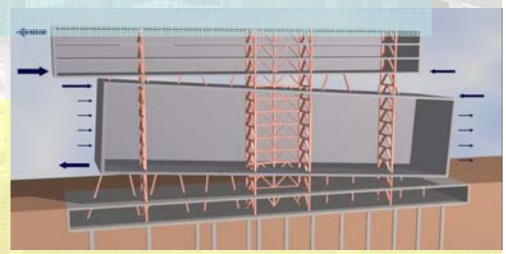
- **OWNER: Blackfriars Investment and Royal London Asset Management**
- **ARCHITECT: Alsop Architects**
- **MEP ENGINEERS: Buro Happold Ltd.**
- **GENERAL CONTRACTOR: Skanska UK**
- **ELECTRICAL CONTRACTOR: Buro Happold Ltd.**
- **STRUCTURAL CONTRACTOR: Buro Happold Ltd.**



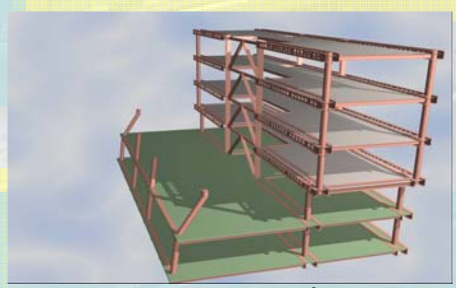
Mechanical

- Good BREEAM Rating (equivalent to LEED rating)
- Gas-Fired central boiler system
- Centralized Chiller Plant
- Mechanically Ventilated due to Urban location
- 4-pipe fan coil system with units placed within structural grids to achieve most versatile open space floor plan available

Structural



- Two-story raked columns at Ground and 7th levels
- Steel Construction with Concrete Slab Flooring
- 9m cantilever achieved through fully fixed Vierendeel girder from 9th to 12th floors tied to cores.



Lighting/Electrical

- 4 MVA Substation servicing Palestra and surrounding buildings
- 2 – 1600 amp, 1000 KVA transformers feed Landlord roof plant
- 4 – 800 amp, 500 KVA transformers feed Tenant Load
- 415V 3 Phase Service to Tenant areas.

Construction Features

- The proximity to the Jubilee line on the Underground required all lifts to be under 8.5 tons, resulting in the use of composite steel beams, structurally efficient, lightweight, and easy to assemble on site.
- More steel used in the 7th-9th floor than the 3rd-6th levels combined.

www.arche.psu.edu/thesis/eportfolio/current/portfolios/rsa126/

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I. Executive Summary

This report studies the energy optimization of The Palestra Office Building in London, England, by analyzing proposed systems such as an IC engine-driven chiller plant, Dedicated Outdoor Air System (DOAS) as well as the integration of Solar PV Cells and Wind turbines and their acoustical impact on the design. This research was carried out while following the guidelines set forth by The Pennsylvania State University Department of Architectural Engineering.

A variety of resources, references, and software programs were utilized to complete the study of the chiller plant, ventilation system, and ‘green’ technology opportunities, including Trane’s™ Trace® 700 program and RETScreen® International Clean Energy Act Analysis Software. These materials were used to create the application of the engine driven chiller plant and Dedicated Outdoor Air System for the Palestra Building. Following the mechanical analysis of these systems it was found that with the addition of the engine driven chiller plant produced 22,886,070 kWh savings in annual energy consumption, and an 8.7% reduction in Life Cycle costs. The analysis of the DOAS design resulted in a 27,776,698 kWh savings in annual consumption, and a 10.31% reduction in Life Cycle costs. Due to the improvements that each system had on the overall efficiency of the building, an analysis was completed with the integration of both designs. This ‘hybrid’ design resulted in a 28,985,950 kWh annual savings, and a 10.2% reduction in Life Cycle costs. This proves that the proposed designs provide excellent financial savings, as well as a reduced environmental impact, which is the prime focus of the newest building regulations in the UK.

In addition, breadth work was completed on secondary topics, including the acoustic levels of the new chillers, as well as, the addition of green technologies such as Solar PV panels and Wind Turbines. A Composite Noise Rating analysis was completed for both the existing and proposed chiller plants, finding that there was not an increase in the noise level dramatic enough to warrant the installation of additional acoustic barriers at this time.

The study of the Solar and Wind energies provided mixed results. These additions are driven by the newest tenant for the building, and due to the timing of their request so late in the construction phase the layout of the equipment on the roof is already confirmed, creating obstacles for installing equipment that depends so heavily on placement, orientation, and floor area. Combined with the low average wind speed in London, both systems had a less than desirable payback period, 9 years for the Solar panels and over 2000 years for the Wind Turbines. It is strongly recommended that the owner abandon the idea of a wind system and out the additional roof area and funds into improving the efficiency of the Solar system.

II. Acknowledgements

This report and all the research required to complete it would not have been made possible without the support and mentorship from numerous individuals and companies.

First, I would like to thank my parents, Pam and Rick Allen, as well as my sisters, Katie and Christy. They have been my greatest supporters and the rock I have leaned on from the day I decided I wanted to be an Architectural Engineer from Penn State.

I would also like to acknowledge the people that made my research possible by providing me with the resources, materials, and guidance I needed: Pirooz Kani and Robert Okpala, Buro Happold; Stephen Fox, Skanska; Blackfriars Investments, Building Owner.

*A special thank you to Buro Happold for awarding me with the Happold Trust Scholarship, and granting me an internship in their London office. The opportunity to experience the engineering industry from a more worldly perspective was a life-changing experience that has profoundly impacted my research.

This also would not have been possible without the Architectural Engineering faculty. It is because of your passion for our industry that I have also come to love building services so much. The most important lesson you have given me is that learning doesn't stop at the classroom door; I will be a life-long learner. And thank you Professor Moses Ling for all of your encouragement over the years, from my first Honors option with you on Green Design to

study abroad opportunities and advice on real life. Your faith and dedication have truly inspired me.

In addition I would like to thank the Pennsylvania State University Schreyer Honors College for their financial support, allowing me to arrange a site visit to London to continue my research.

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III. Introduction – Project Background

The fifth-year curriculum for Architectural Engineering students includes a year-long design project, where each student selects a recently renovated or constructed building to study and examine its systems. All design documents and specifications are donated by the project's owner, engineers, and contractors. The first half of the year is spent writing three technical papers on the existing conditions of the design looking at its code compliance, energy efficiency, utility consumption, and budget. Once a good sense of the building's systems has been gained a redesign is proposed to increase the efficiency of the existing design. This proposal must include a detailed analysis within the student's area of specialty (lighting/electrical, mechanical, structural, construction management), as well as two additional studies into non-option areas. The second half of the year is then spent implementing the design schemes set forth in the proposal. The year ends with the completion of the final thesis report and presentation to the jury consisting of Architectural Engineering faculty.

In addition to the research and analysis, each student is required to create and maintain a Capstone Project e-portfolio (CPEP) website displaying their progress throughout the year. This includes all technical reports, proposal and building information. The website serves as an excellent means of communicating our work with design professionals and faculty as well as fellow students.

This report is a culmination of a year-long study to optimize the design of the Palestra Building in London, England with an emphasis on mechanical, solar, wind, and acoustical systems. The report presents the feasibility the proposed designs and their impact on the overall scheme of the building. These findings are available only for educational purposes, and will be shared only with the afore mentioned sponsors.

IV. Building Background

Architecture and General Information

The Palestra development is currently the largest office building currently under construction in London, England. Located across the street from the Southwark tube station, and just minutes from the Tate Modern museum as well as Waterloo Station, Palestra was destined to be a high-profile building. The location only enhances the 'quirky' design of the architect, Will Alsop from Alsop Architects in London.


Figure 3.1 Palestra under Construction

This twelve story design is not your average office building, incorporating many dramatic features including two-story 'dancing' columns, large cantilevers, and tilted façade. The raked columns on the 1^{st} and 7^{th} stories were dubbed 'dancing columns' for the movement perceived by the observer due to the striking angles they are erected at. The entire design team finds humor in the community's reaction to Palestra. One concerned neighbor even wrote a letter to the project manager voicing concerns about these columns that were severely out of plumb, not realizing the intention of the architect.

The average passerby also notices that the building appears to be two large boxes set atop one another. This effect is achieved at the 9^{th} story where there is a 1.5 meter overhang on three sides of the building, and then a spectacular 9 meter cantilever overhanging Blackfriars road on the fourth side. The result is very much a floating effect where there are no visible signs as to how the top box is held in place with the absence of any diagonal bracing or tensioned cables.

Accenting these unusual yet inspiring characteristics is the slanted façade present on the lower 'box' enhancing the raked columns. All of the floors are horizontal while the façade is at an ll degree slant. This degree is sufficient enough for the façade to touch ground level on the east side while elevated 2 stories high on the west side. This creates a very appealing and open pedestrian walkway while creating an inviting entrance to those travelers exiting the tube station.

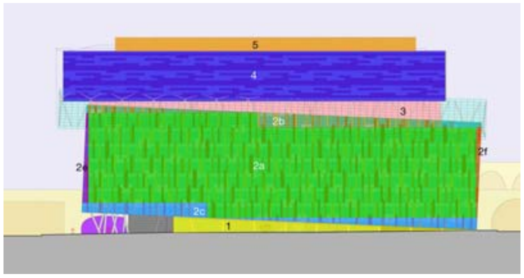


Figure 3.2 North Façade Elevation

Building Envelope

The building is fully glazed, with acoustic glazing on the North and West sides of the bottom 'box,' utilizing 5 different types of double glazing. There is an additional colored ceramic frit pattern across the façade incorporating three colours. These ceramic frits are 60% solid and 500mm wide.

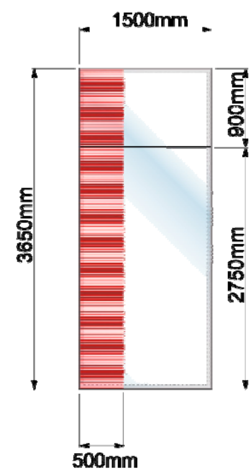


Figure 3.4 Typically Glazing Panel

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. Efficient use of systems and controls and any further energy saving measures will ensure that the above targets are achieved and the impact of the building on the environment is minimised.

Construction

Build-ability was a large concern from the beginning of the design process for Palestra because of the site's close proximity to roads, the main railway line from Charing Cross, and the Jubilee line on the underground. Any crane over 8.5 ton is deemed a 'controlled lift' requiring special supervision from National Rail, so every effort was made to remain below this weight. The result was composite steel beams that were structurally efficient as well as


light-weight and east to assemble on site. The steel frame was also strong enough to hold its own dead loads, so that the slabs could be poured at a later date.


Figure 3.5 Steel Erection on Palestra Site

Because there was a substation located in the basement of the existing building, a temporary substation also needed to be erected on the Gambia street side to service the site and several surrounding buildings during the construction process and to decommission and remove the old substation as well.

Primary Project Team

Owner: Blackfriars Investments and Royal London Asset Management

- **Website:** www.blackfriars-uk.com, www.rlam.co.uk

Architect: Alsop Architects (Will Alsop)

- **Website:** www.alsoparchitects.com

MEP Engineers: Buro Happold Ltd.

- **Website:** www.burohappold.com

General Contractor: Skanska UK

- **Website:** www.skanska.com

Structural Engineers: Buro Happold Ltd.

- **Website:** www.burohappold.com

Building Systems

ELECTRICAL

A 4MVA substation will be installed in the basement plant room to service Palestra and surrounding buildings formerly dependent on the substation in Orbit House. The load will be fed by 4 transformers of 1,000kVA, 1600 amp, each with a capacity of 2 No. 1600 amp, 1000kVA low voltage supplies from this substation would feed landlord plant on the roof. 4 No. 800 amp, 500kVA low voltage supplies service tenant load via busbar risers.

Tenant supplies are based on following electric loadings:

Lighting	15W/m^2		
Small Power	30W/m^2		
FCU	15W/m^2		
Sub-Total	60W/m^2		
Office Area	26,000 m^2		
Total	1560kW	1835kVA	2780amp

The busbars extend to roof level with a capacity of 4 x 800 amp = 3200 amp, leaving 420 amp, 275 kVA capacity not used by the tenants. This supplies the Landlord's non-essentials loads in the basement and at ground level. Then the landlord main distribution board can be located on the roof adjacent to the main landlord loads.

The main landlord switchboards in the basement feed…

- Boilers and associated pumps
- Sprinkler pumps
- Entrance area lighting and power
- Car Park and plant room lighting and power
- Core Lighting and power on Levels B to 5
- Substation Ventilation

- External Lighting
- Security/Fire control center
- Water tanks and associated pumps
- Loading Dock Lighting and power

The two main landlord LV switchboards at the roof level will be fed by 1600 amp supplies in XLPE/SWA/LSF cables/busbars from the LE substation, via isolators in the basement, so the service can be isolated by the landlord's staff without entering the LE substation.

Each of these main switch panels will have the facility to incorporate power factor correction equipment to achieve an optimum power factor of 0.95 lagging.

Four tenant distribution boards are provided on each floor serving the area corresponding to one tenant and fed by metered tap-offs from the busbar risers. These boards feed the lighting, Fan Coil Units (FCUs), and a small number of 'cleaners' sockets on the cores. There will also be a raised accessible flooring system to provide electrical and data services with maximum versatility.

Back-up power supplies for Fire Alarm, emergency lighting, voice alarm, BMS head-end, security systems will be provided by battery power.

LIGHTING

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 complying with the requirements of LG3 category 2. The lighting will be arranged on a 'checkerboard' grid with 2.1m between fittings. All luminaries will be plugged into a lighting relay box mounted in the ceiling. This will allow for local switching to be installed as partitions are moved around by the tenant, as well as space for additional luminaries to be installed. These ‘cores’ will also allow for future linking of automatic time-based switching and daylight control.

When possible in the office areas low energy compact source lamps will be installed for energy efficiency and ease of maintenance.

The car park and plant room spaces will be fitted with robust fluorescent fittings with lighting controls designed to minimize lighting of unoccupied spaces.

External lighting will be designed in partnership with the Architect, but will provide adequate lighting for security and closed-circuit television (CCTV).

Lighting in toilets, stairs, toilet lobbies, and car parks will be controlled by presence detectors. Lighting in the main lobbies will be BMS time clock controlled to correspond with the tenant occupancy levels.

Emergency lighting will be battery units with a three hour life at reduced output, and where possible they will be integrated into the general luminaries.

MECHANICAL

The Palestra building is equipped with a gas-fired central boiler and chiller plant. And due to the close proximity to surrounding structures as well as the public transport, high quality fresh air is limited requiring a mechanically ventilated design.

The boiler room is located on the roof, 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 (FCU), and heater batteries.

Fig 3.6 Existing Air-Cooled Screw Chillers

Fig 3.7 Boiler Pump in Rooftop Plant

Fig 3.8 Central Boiler Plant

The chiller plant is located on the roof and consists 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. On the office levels the owner required the design team to achieve a versatile open floor plan layout. Therefore one FCU was placed in each structural bay. Depending on the desired office layout of the tenant more FCUs can be added for increase climate control for the employees. This is based on a four-pipe fan coil system used on each office level, including water-side controls for responsible operation, room temperature sensors, and variable speed heating and chilled water pumps to conserve energy.

Because the reception area could be operating 24 hours, it was found to be more efficient to have an independent system to run separately at off-peak hours. This area is mechanically heated, cooled and ventilated in the same manner as the rest of the building. However instead

of the standard FCU a Direct Expansion FCU was chosen, utilizing heat pumps rather than LTHW or chilled water.

To meet the minimum fresh air requirements two roof-mounted fresh air ventilation plants were installed.

All mechanical components are routed through the building's BMS (Building Management System) to maximize efficiency.

STRUCTURAL

Fig 3.9 Steel Framework of Palestra

The structural systems of Palestra are probably one of its main selling points. As previously mentioned there are two stories of double height 'dancing columns' (raked) on the Ground-First floors as well as the 7th - 8th floors. Each column is paired so that when one is leaning one way, there is another column leaning the exact opposite. However, the pairings are spread out so that this isn't quickly apparent to an observer. While these loads balance one another, they also create a strong twisting moment in the floor slabs that is directed to the stair and lift cores which use the conventional steel K-braced frames.

Fig 3.10 Raked Column Design

There a larger 9m cantilever on the west side of the building as well. Because the architect placed firm restrictions on the use of diagonal bracing and more traditional support methods the result is a fully fixed Vierendeel girder from the 9th to 12th floors and tied to the primary cores. This member is made up of very substantial plate girders with flanges made from 70-80mm plates. There is as much steel on the ninth floor as the third through sixth floors combined.

Everything between the first and seventh floor is vertical. Then there are two stories of 'dancing columns,' and at the ninth floor the steel grid changes from 10m x 7.5m to 12m x 7.5m because of the 1.5m cantilever all around. Due to this transition none of the columns from the 8th floor meet those on the 9th and the entire grid is offset to the west by 7.5m.

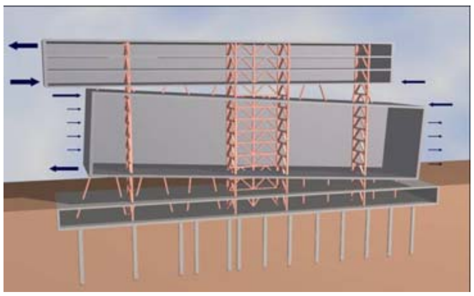


Fig 3.11 Lateral Load Schematic

FIRE PROTECTION

Provision has been made for mechanical smoke extract to exit through the current ventilation extract system, extracting up to 6 air changes per hour. In basement areas the 10 air changes per hour will be provided. The loading bay will be naturally ventilated with 2.5% of the floor area open to fresh air.

The upper floors will have sprinkler systems installed, following BS 5306 Part 2 regulations. Basement and ground floors' sprinklers will be serviced by the town mains, while the upper floors will be serviced by a 180 cubic meter water storage tank in the basement. The system is distributed to the east and west cores and rise throughout the building.

Two fire fighting shafts shall be provided with smoke control within each shaft using the alternative 'chimney' design of smoke shaft following BRE standards. Each shaft will also be fitted with a dry riser with an outlet at each fire fighting lobby and inlets located at ground level.

PLUMBING

There are 2 No 150mm fire supplies from alternate water supplies in Blackfriars Rpad and Union Street. There are also three water supplies entering the site, one on Blackfriars Road, one in Union Street, and one in Gambia Street. The Blackfriars supply will service the building's domestic water demands because the supply on Gambia is only 100mm diameter and the 175mm main in Union is already servicing the fire main.

The building's demand is approximately 4.1L/s with a 4" main.

TELECOMMUNICATIONS

Communication risers will be provided at four locations around the building with two risers servicing each tenant. Using galvanized cable trays the risers can handle copper, fiber optic or blown fiber cables as required by the tenant.

Landlord installation will include a structured data cabling scheme servicing the plant rooms, lift motor rooms, reception, and one outlet per tenant area (4 outlets per floor). A landlord telephone exchange will be installed to provide for future additions to a building telephone exchange connection. The BMS and Access Control terminals will also be connected through the structured data cabling system.

Tenant installation will include the installation and routing of data cabling from wire closets to user equipment through access flooring provided. Communication links between the communication risers is limited but can accommodate for fiber optic or multi-pair telephone cables.

TRANSPORTATION

The central passenger transportation will consist of seven lifts located in the central core. Each lift will be sized at 1600kg/21 persons each, operate at 1.6 m/s, and meet disabled access requirements, achieving a waiting time of 30 seconds as recommended by BCO. Each lift will service all twelve floors, with one serving the basement additionally. The basement access will be monitored through a card swipe controlled by the BMS. The lift motors will be located in the roof plant area.

Two 630kg/8person fire fighting lifts have been provided, one in the east core and one in the west core following BS 5266 and BS 5588. They will have electric traction lift drives and operate at 1 m/s and will service ground floor through the 11th floor.

An additional goods lift is located in the east core of the building. The good lift is 3000kg/40 persons and will also have the electric traction lift drives and service -1 through 11. The motor room will be located in the roof plant area, with an additional hoisting system on the 11th floor to lift materials onto the roof.

SPECIAL SYSTEMS

Security

A security system will be installed providing CCTV, access control, entry phone, and intruder detection. CCTV cameras will be located at all entrances and lobby areas in the building and will run 24 hours a day. A card access system will allow access into the building and then between certain areas within the building (i.e. basement lift).

Lightning Protection

A lightning protection scheme will be provided to fully protect the building, its contents and occupants against possible lightning strikes. Generally an air termination network is installed across the site, providing an inter-linked grid pattern of high conductivity copper tape located at roof level. A down conductor network will be provided around the perimeter, leading to the earth termination network via a test link.

Building Management System (BMS)

The system should have the ability to monitor and or control the following

- Heating, Ventilation and Comfort Cooling Plant and equipment
- AHU plant (fans enable/disable and status<alarm>, filter status <alarm>, flow <alarm>, damper/valve monitoring)
- Chiller
- Boilers (if appropriate)
- FCUs in tenanted areas to be fitted with controllers and networked for monitoring and control.
- Pump(s)
- Pressurization Unit
- Toilet Extract Fans
- Gas Valve
- Car Park extract system
- Basement ventilation system
- Cold water booster sets
- Electricity, gas and chilled and low temperature hot water meters
- LV distribution networks
- Fire and Smoke Control System
- Fire Alarm Systems
- Automatic Sprinkler system
- Emergency Generators
- Lifts

V. Mechanical Depth

a. Existing Conditions

Approach and Strategy

Figure 5.1 Palestra Under Construction

The Palestra Building is the result of a business collaboration between Insignia Richard Ellis Development and Blackfriars Investment. The team wanted to create an iconic landmark office building in southern London as an effort to spur regeneration in the area. In addition to an exciting and contemporary design, great efforts were made to develop the most efficient building from an engineering standpoint as well. With the complex structural systems incorporated throughout the building with the ‘dancing columns’ and 9 meter cantilever, careful integration of the building services distribution systems was imperative. Due to the ‘glass box’ nature of the design, a detailed solar shading study was completed to ensure system efficiency with minimal impact on the views from the office space.

Key Objectives

- At least 280,000 square feet of office space
- High Asset Value
- Flexible design to meet current and future business needs
- Design should comply with design specification set forth by Insignia Richard Ellis
- Flexible enough to allow for multi-tenant occupiers, up to four per floor
- Minimal impact on Building Services as office layouts are modified
- Cost Effective and Economic design
- Energy Efficient with Low Operating Costs

Occupied Environment

Temperature: The air and radiant temperatures shall meet the occupant's perception of their thermal environment comfort zone.

Air Movement: In order to meet the fresh air requirements for comfort while avoiding draughts the air velocity shall be limited to 0.15m/s in the winter and 0.25 during summer conditions.

Indoor Air Quality: To maintain appropriate contaminant levels (including C02) from office equipment and equipment the ventilation system shall be designed for 10-16L/s per person.

Humidity: Due to the moderate climate found in London, England the only critical season is winter when the humidity level can fall below 30%.
Acoustics: Too much background noise can be distracting, however a moderate amount has been proven to enhance concentration and disguise general conversations.

Lighting: Adequate levels of lighting must be provided throughout the building, yet it must be of the appropriate quality and also coordinate with the day lighting studies.

In addition to these specific strategies it is important to note that when utilizing air as the predominant means for heating and cooling internal spaces you will be able to satisfy up to 80% of the occupants. And through the fan coil unit layout chosen for the Palestra building limits the amount of humidity control the occupants will have, however the humidity levels should remain between 35-65% most of the year. However individual user controls will also be provided to account for the psychological aspect of how an occupant perceives his/her thermal environment.

Additional design criteria are summarized in Table 5.1.

Table 5.1 Design Criteria

Design Parameter					Comments
Outdoor temperature	Winter -4°C sat	Summer 29°C db, 20°C wb			
Internal temperature	Offices 22°C ± 2	Toilets & Stairs 18°C min (Winter)	22 °C ± 2	Toilets & Stairs uncontrolled (summer)	The internal temperatures specified are more onerous than the BCO recommendations and will increase the building maximum demand and year round energy consumption.
Air Movement	Winter 0.15m/s max Summer 0.25m/s max				To avoid stratification when heating is required the 0.15 m/s criteria can be relaxed for systems supplying at high level.
Relative Humidity	35 – 65% areas conditioned by fancoil systems (expected levels – note the humidity levels are not controlled). Other areas no control.				Initial installation will not contain humidity control. Space shall be provided within the office area AHU on the roof for future tenant installation of humidification system.

Heating and Cooling Loads

The system was designed to handle 1796 kW of heating loads and 3871 kW of cooling to the building. The heating is supplied through a central gas-fired boiler plant located on the roof, while the cooling is provided through a central air-cooled chiller plant also located on the roof. For a further breakdown of the loads please refer to Appendix A.

Air-Side Systems

The air-side ventilation system in the Palestra Building consists of a constant volume system served by seven different air handling units. Four of the AHUs are located on the roof, two are located in the basement plant room, and one is located in the level 1 mechanical space.

Air Handling Units 1 and 2 are located on the roof and supply air to 16107m^2 of open plan office space disbursed evenly throughout the twelve levels at a rate of 38,139.84 cfm. Each AHU maintains a negative pressure of 500 Pa, and includes a heat exchanger in the form of a heat wheel, a cooling coil, a heating coil, a panel filter of grade G4, and a variable frequency drive supply and extract fan.

Air Handling Units 3 and 4 service the building’s water closets and are also located in the roof ventilation plant. Unit 3 supplies air to 498m2 of toilets on the west side of the building, and Unit 4 supplies ventilation to 627m2 of toilet space on the east side. Each unit is sized to supply 6,420.21cfm to their respective areas. These are constant volume systems, and each includes a frost coil, cooling coil, heating coil, as well as supply and extract fans.

Air Handling Units 5 and 6 are located in the basement plant room. Units 5 and 6 are design to serve as extract systems for the toilets as well as the sprinkler plant and boiler rooms. Each unit includes a panel filter of grade G4, a cooling coil, and a heating coil. Units 5 and 6 were designed to provide adequate smoke clearance to these vital mechanical spaces with a flow of 6,356.64 cfm. Approved Document F requires a minimum of 12 m/s face velocity for ventilation extract in the case of fire.

Air Handling Unit 7 is located in the Ground Floor mechanical room and solely supplies air to the reception area, 772m2, at a constant volume flow rate of 7,627.97 cfm. This unit contains a heating coil, cooling coil, a panel filter of grade G4, as well as, supply and extract fans.

Water-Side Systems

The Palestra Building's water-side systems consist of a centralized boiler and chiller plant. Cooling is provided through a chiller plant located on the roof and consisting of seven 537 kW packaged air-cooled chiller units, six of which run at full load daily, while the seventh serves as a backup unit. The total estimated cooling load for the building is 3,291 kW. Chilled water is provided to the building at 7ºC and returned to the plant at 12ºC. 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 is provided through a natural gas-fired central boiler system. The boiler room is located in the basement, and runs on four 800 kW boilers, three of which run at 100% to meet 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. The estimated heating load for the building is 2,135 kW. These boilers serve a low temperature hot water system fed to AHU ventilation systems, fan coil units, and heater batteries and operate with an 11ºC differential.

In addition to these systems there are 314 fan coil units placed on a grid system throughout the building to maximize thermal comfort. The grid layout reiterates the design goal to create office spaces that will meet the needs of current and future tenants. Depending on the desired office layout of the tenant more FCUs can be added for increase climate control for the employees. This is based on a four-pipe fan coil system used on each office level, including water-side controls for responsible operation, room temperature sensors, and variable speed heating and chilled water pumps to conserve energy.

Critique of System

The existing mechanical systems in the Palestra Building were well-designed and efficient, with the emphasis maintained on the ability of the system to be flexible, catering to its tenants (current and future), as well as creating a high level of reliability and redundancy.

The centralized boiler and chiller plant will be very useful in the coming years as more efficient technologies come along. Having all of the systems in one location will make it easy to replace them at once rather than disrupting locations throughout the building as would be require with localized heating and cooling systems.

In order to maximize the versatility and flexibility of the rentable office space the design team created open floor office plans with fan coil units placed on a grid system. This allows the space to function well with minimal walls and obstructions. However if the tenants desire more of a closed office layout, or would like to provide their employees with more personalized control over their environment more fan coil units may be added to this grid, with additional capacity on AHU-3 and AHU-4 to handle these possible loads.

Accessibility to the main plant rooms was also well-designed with thought put into how future replacements for all of the equipment will be moved in and out. The fan coil units throughout the design are located in the suspended ceiling and can be accessed by removing the acoustic ceiling tiles.

The design team also made a smart choice in selecting the 4 pipe fan coil system, and providing gas heating versus a 2 pipe unit using electric heating. Not only does Gas provide a much lower life cycle cost, but it is releases fewer emissions into the environment thus earning more ‘Green’ points which was a prime objective with the Palestra Building.

With all the benefits of the system and the forward thinking of the design team, there is no set means to control the humidity levels in the building. It is noted that London, England is a

very moderate climate with minimal humidity issues through the spring, summer and fall seasons. However, there is a tendency for the humidity level to drop below 35% during the winter months. Accommodations have been made to allow for future installment of humidifiers in the Air Handing system as needed. Investigation into the feasibility of a dedicated outdoor air system could be a possible response to the humidity control issues. A closer look at what efficiency was compromised in order to maximize the flexibility would also be valuable, and how much efficiency the Building Management System can compensate for.

Alternatives Considered

Several schemes for a mechanical redesign of the Palestra Building were contemplated during the research of existing systems. These included a Combined Heat and Power plant, Day lighting Aperture Optimization, and possibly reducing the number of air handling units.

Building Combined Heat and Power (BCHP) is becoming increasingly popular as a means to increase system efficiency and thus decrease emissions by fully burning more of the energy inputted. With the new emission regulations outlined in Approved Document L and the increasing rates for electricity this seemed to be an interesting solution. However BCHP requires a large amount of waste heat and a fairly constant demand load to be most successful. One possibility was to coordinate a system between Palestra and the surrounding residential buildings to balance each buildings' demand peaks, as well as provide the necessary amount of waste heat. The Palestra already shares an electrical substation in its basement with several surrounding buildings, so this would have been a continuation of the current setup. This proposal would require extreme coordination with many stakeholders, and also require a large amount of floor space in the Palestra Building which is at a premium. The commitment on behalf of Palestra's owner would significantly increase, which may not be of interest to them regardless of the long term gains.

Maximizing the benefits of day lighting can have a large impact on the energy efficiency of a building, especially within the Palestra Building's 'glass box' design. By increasing the window efficiency and minimizing the glazing area the overall design could benefit from the increased insulation. However, due to the extensive research already done in this area by the design team, there is little probability that a better design could be achieved without sacrificing the design's architectural integrity. Therefore the efforts of this research would be better served investigating other topics.

Reducing the number of air handling units was also a consideration. Currently there are seven units servicing the building. Two units are dedicated to servicing the toilet areas, two serve as extracts to the toilets and plant spaces, one supplies the basement and lobby, and two additional units service all of the office space. It seems a bit imbalanced to have two units supplying over 80% of the floor area, while five smaller units were included in the design to serve such little area. However, this design does have excellent redundancy and it has additional capacity to meet future demands according to the tenant and office layout. In the end due to the lack of operable windows in the design, and the need for the system to meet current and future occupant demands to maximize desirability and profit it was decided that this system is effective as currently designed.

b. Chiller Plant Optimization

i. Proposed Redesign: IC Engine-driven Chiller Plant

Proposed Redesign and Justification

Building design in the United Kingdom is currently undergoing some significant changes with respect to emissions and energy consumption. Across the country there has been a dramatic increase in natural gas consumption over the past decade as electric generation has become more dependent on gas. Compared to other energy resources available gas is still the cheapest and most efficient option for consumers. Following the publication of the Fuel Poverty Strategy in 2001 the leaders of the country have been encouraging increased coverage of the gas network. In a recent publication from the Department of Trade and Industry in the UK, The Fuel Poverty Strategy reported that the lack of access to gas mains was the main cause of fuel poverty in 54% of the households included in the study. This is a dramatic example of the value of gas-driven systems in the UK today. Thus it was deemed beneficial to look into a natural gas-based system for the Palestra building.

The largest electrically-driven plant in this urban development is the existing chiller plant. The current design includes seven 535 kW air-cooled screw chillers produced by McQuay. This report will look at the advantages and disadvantages of replacing the electric chiller plant with an IC engine-driven plant coupled with the current gas-fired boiler plant.

The current chiller plant in the Palestra Building utilizes electric chillers and provides 18% additional capacity on the system. While this system functions well in the space, it accumulates large operating costs in order to meet the peak electric loads during the day. The current spark gap between peak electric and gas utility costs is over 3 pence per kilowatt-hour. A gas-based system not only allows for greater efficiency onsite, but the use of current and future technologies such as thermal storage and other forms of heat recovery. That flexibility

could prove beneficial in the future as the Emission Regulations in the UK become more and more strict. Flexibility was one of the driving factors throughout the rest of the design, and should be carried through here.

A hybrid system with IC engines and gas turbines was also considered but due to the low base load for the building it will not be included in these calculations. Although the building is not fully operating yet, the calculations have been based on a previous project with a similar expected load profile. Thus it was deemed more worthy to analyze an IC engine driven chiller plant.

Calculations

Trace™ 700 was used for all of the energy simulations. Trace™ 700 is a software program developed and distributed by Trane®, with the ability to model HVAC systems, economic and utility constraints to easily compare design alternatives.

Table 5.2 Tecogen Gas Engine Driven Chiller

Type	Water-Cooled
Series	STx Series
Model	CH-200x
No.	7
Full Load Rating	200 ton
Fuel Consumption	42.36 m^3/h
Chilled Water Flow	1.81 m^3/min
Physical Data	
Length	4.214 m
Width	1.32 m
Height	2.057 m
Weight	9842 kg

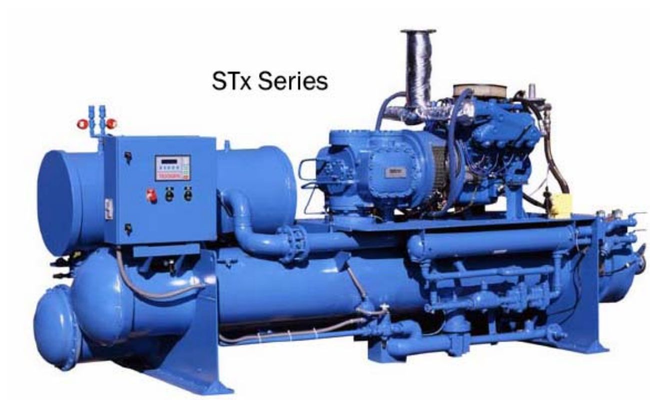


Figure 5.2 Tecogen Chiller

Here five 200 ton (703kW) water-cooled IC engine chillers were selected to meet Palestra's cooling load of 3,291 kW. This size allows for moderately-sized chiller unit, while maintaining high percentage loads, redundancy, and additional cooling capacity that is built into the current design. However with fewer units each weight more than double the original electric units it was important to keep the necessary amount of equipment to a minimum for structural purposes.

Table 5.3 Utility Rates - London, England

Electric	
Day	4.592 p/kWh
Night	2.658 p/kWh
Supply Point Charge	55.88 £/month
Availability Charge	106 p/kVA
Gas	
per unit	1.515 p/kWh
Water	
per unit	88.85 p/m^3
Fixed cost for connection	860 £/year

***p, pence**

The design conditions were inputted in accordance with Table 5.1 and Table 5.3. Due to the fact that Palestra is still under construction the utility rates listed are based on another project of similar size and scope.

Results

Table 5.4 Trace™ Energy Consumption Data

	Original Electric Scheme		Proposed Engine Scheme	
Monthly Energy Consumption	Energy, kWh	Cost, £	Energy, kWh	Cost, £
Electric	20,394,152 kWh	£937,840.56	12,803,427 kWh	£589,274.44
Gas	8,288,669 kWh	£14,622.22	8,182,627 kWh	£14,435.56
Water	--	--	4,285 kL	£11,325.56
Total Monthly Utility Cost		£952,462.78		£615,035.56
Total Yearly Consumption	69,913,486 kWh		47,027,416 kWh	
Life Cycle Cost		**£17,704,689.24**		**£16,163,972.20**

The existing heating and airside systems were integrated with the new chiller plant, and the energy and cost simulation results are summarized in Table 5.4. As compared to the original electric scheme the gas engine driven plant decreased the yearly energy consumption by 33%. There are significant savings in electrical usage, reducing monthly consumption by 7,590,725 kWh and £348,566, which could continue to increase as the price of electricity rises relative to the natural gas rate. On the whole the life cycle costs can be reduced by an additional 8.7%.

Table 5.5 Electric versus IC Engine Chiller Costs

Type	Electric Air-Cooled Screw	Water-Cooled Engine Driven
Cost Per Unit	£51,320.00	£103,625.00
No. Units	7	5
Total Cost	**£359,240.00**	**£518,125.00**

Despite the energy savings, it is important to note the difference in first cost for each system (Table 5.5). While an electric air-cooled screw chiller costs approximately £360,000, an engine driven chiller is almost £520,000. However, the 44% in capital cost is more than accounted for by the energy savings as shown in the Life Cycle Cost reductions.

Overall, the gas-engine driven chiller plant could provide significant savings for both Palestra's owner and tenants. And with the long term energy crisis in the United Kingdom, a gas-based system is a smart choice. The other considerations that should be taken into account are the weight of the new equipment and its structural impact on the building, the increase in acoustic levels due to the engines, and the actual first costs. Many times the Utility or government programs will supplement your initial costs when you select an energy friendly product.

b. Ventilation Optimization

i. Proposed Redesign: Dedicated Outdoor Air System with Chilled Beams

Proposed Redesign and Justification

The second proposed design is the installation of a dedicated outdoor air system (DOAS) supplemented with chilled beams throughout the occupied spaces. DOAS not only reduces the ductwork and equipment sizes, but also increases humidity control and reduces energy and first costs. This system meets the latent loads by providing dry outdoor air at low temperatures, while the sensible load is accounted by using the chilled ceiling beams. An additional benefit of this system is the increased indoor air quality. DOAS could prove to solve several of the design challenges that faced the Palestra Building regarding its urban location and lack of humidity controls.

In a 100% outdoor air system such as this the air handling units (AHU) are sized to provide the minimum amount of fresh air required based on function and occupancy of the space. These guidelines are set forth in ASHRAE Standard 62, and those values for Palestra are listed in Table 5.7. In addition an enthalpy wheel is installed in each AHU to maximize heat recovery while also providing excellent humidity control where there currently is none. This equipment will meet all of the building's latent load, and 38% of the sensible load. The remainder of the sensible load will be controlled by chilled beams suspended from the ceiling within the open office spaces, as shown in Figure 5.3.

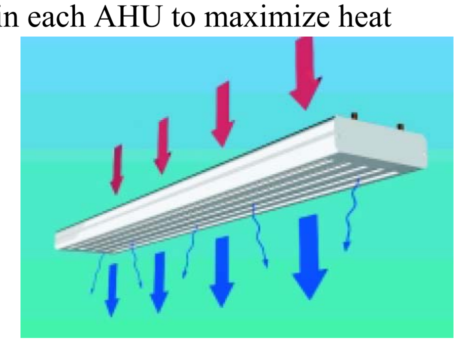
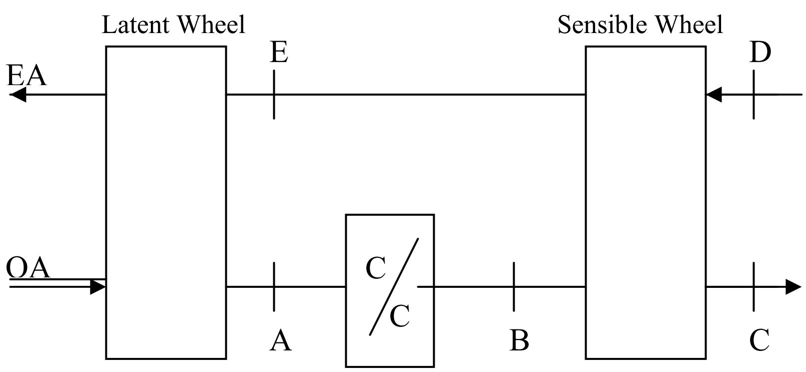


Figure 5.3 Chilled Beam Diagram

The greatest fault with DOAS is the likelihood for condensation to form if the supply air temperature would drop below the dew point of the space. Fortunately in the UK where the weather is quite mild compared to most regions in the United States, the chance of that happening is greatly decreased.

Calculations

Specifying Set points in Office Air Handling Units



Latent Load:

Occupancy = 1100 people per unit

Q_latent = .0586 kW/person

Q_lat = .0586kW*1100 = 64.46kW (220,000 Btu/h)

Outdoor Air Conditions:

Dry Bulb Temperature = 32ºC

Humidity Ratio = 0.015 kg/kg

Space Air Conditions (Point D):

Dry Bulb Temperature = 26ºC

Humidity Ratio = .0093 kg/kg (65 gr/lbma)← moisture content of dry air

Supply Air Temperature: 22ºC

Enthalpy Wheel Selection:

Manufacturer: Novelaire Technologies

Model: ECW1086

Volume Flow Rate = 7644.7 L/s (16200 cfm)

Latent Effectiveness → $\varepsilon_l = 0.76$

Sensible Effectiveness → $\varepsilon_s = 0.79$

Pressure Drop → $\Delta p = 0.74$ inches wg

Face Velocity = 520 sfpm = 2.62 m/s

Design Conditions at Point A:

$W_{OA\text{-}EW} = -\varepsilon_l * (W_{OA} - W_{EA\text{-}SW}) + W_{OA}$

$= -(.76)*(0.15 \text{ kg/kg} - 0.0093 \text{ kg/kg}) + 0.015 \text{ kg/kg}$

$= 0.0107$ kg/kg

$DBT_{OA\text{-}EW} = -\varepsilon_s * (DBT_{OA} - DBT_{EW\text{-}SW}) + DBT_{OA}$

$= -(.79)*(32ºC - 23.2ºC) + 32ºC$

$= 25.05ºC$

Design Conditions at Point C:

$Q_{latent} = .68 * cfm * \Delta W$

$W_{SA} = W_{RA} - (Q_{latent}/(.68*cfm))$

= 65 gr/lbma – (220,000Btu/h/(.68*16200cfm))

=45.03 gr/lbma = 0.00643 kg/kg

$DBT_C = 22ºC$

Design Conditions at Point B:

$W_B = -Q_{latent}/(.68*cfm) + W_{space}$

= (-220,000Btu/h)/(.68*16200cfm) + 65 gr/lbma

= 45.03 gr/lbma = 0.00643 kg/kg

[Check: $W_B = W_C$, correct]

$DBT_B = 19.2ºC$

Selecting the Number of Chilled Beams Required

The process used to determine the appropriate square footage of chilled beams in the Palestra Building is described in "Ceiling Radiant Cooling Panels as a Viable Distributed Parallel Sensible Cooling Technology Integrated with Dedicated Outdoor Air Systems" by Dr. Stanley A. Mumma and Christopher L. Conroy.

Step 1: Room Design Conditions

Room Dry Bulb Temperature
-Winter: 22°C
-Summer: 26°C
Relative Humidity: 40-60%
Room Dew Point Temperature: 8-17°C

Step 2: Minimum Rate of Heat Removal Required

Figure 5.4 is taken from the afore mentioned published research by Dr. Mumma and Christopher Conroy and describes the rate of heat removal from the conditioned space based on the room's design dry bulb temperature and relative humidity level.

If 60% RH → 32 W/m^2
If 40% RH → 95 W/m^2

Figure 5.4

Information Pertinent to the CRCP Cooling Selection

Column 1	2	3	4	5	6	7
Room design DBT °F (°C)	**Room design % RH**	**Room design DPT °F (°C)**	**DOAS supply DPT with 20 scfm/person °F (°C)**	**Panel t_{fi} room DPT+3°F °F (°C)**	**Mean panel temp. assuming t_{fi}+5°F °F (°C)**	**Q_s, Btu/h·ft^2 (W/m^2)**
72 (22)	40	46 (8)	37 (3)	49 (9)	54 (12)	30 (95)
72 (22)	60	57 (14)	51 (11)	60 (16)	65 (18)	10 (32)
78 (26)	40	52 (11)	44 (7)	55 (13)	60 (16)	30 (95)
78 (26)	60	63 (17)	58 (14)	66 (19)	71 (22)	10 (32)

Step 3: Calculate Amount of Sensible Cooling Chilled Beams must provide.

Office Area: 31,606m^2

Occupancy: 2202

Combined Sensible Load: 45 W/m^2

Building's Total Sensible Load:

Q_total = 45 W/m^2 * 31,606m^2 = 142,270 W

Outdoor Air Supply: 16 L/s per person

Ventilation Rate:

m_dot = 16 L/s/person*2202 = 35,232 L/s

Sensible Load Met by DOAS:

Q_DOAS = m_dot*Cp*ΔT

Q_DOAS = (35,232L/s)*1.2*(26-13) = 549,619 W

Sensible Load to be met by Chilled Beams:

Q_Beams = Q_total – Q_DOAS = 872,650 W

Step 4: Select Appropriate Chilled Beam

Halton – CLL @ 275 W/m^2 > Minimum Required Rate (32 W/m^2, 95 W/m^2)

Area of Beam Coverage = Q_Beam * Area

= 275 W/m^2 * 31,606 m^2

= 3173.28 m^2

Beam Coverage per Floor = 3173.28 m^2 / 11 = 288.48 m^2

No. Beams per Floor = Floor Beam Area/ Beam Area

= 288.48 m^2 / 4.018 m^2

= 71.80 = **72 Beams per floor**

Total Chilled Beams Needed: 718 Beams

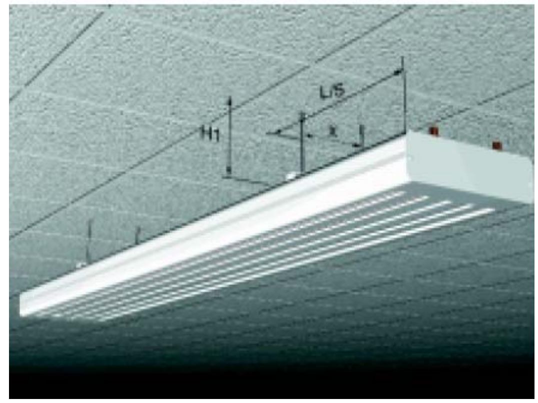


Figure 5.5 Halton CLL Chilled Beam

Table 5.6 Chilled Beam Specification

Brand	Halton
Model	CLL/2- 780-4100; AC=CP/CLL-S,BV
Cooling Capacity	275 W/m^2
Length	4100 mm
Width	780 mm
Height	80 mm

Re-sizing the Air Handling Units

As stated previously, each air handling unit was resized to the minimum outdoor air ventilation required for the type of space each unit serves. That data for each unit is summarized in Table 5.7.

Table 5.7 AHU Resizing

	Original Scheme	Proposed DOAS Scheme	% Difference
AHU -1	18977 L/s	7644.7 L/s	-59.78%
AHU -2	18346 L/s	7600.12 L/s	-58.57%
AHU -3	2332.7 L/s	237.6 L/s	-89.81%
AHU -4	3204 L/s	280.8 L/s	-91.24%
AHU -7	1026 L/s	923.5 L/s	-9.99%

Note that there is a significant decrease in the sizing of Air Handling Units 3 and 4 serving as supply and extract for the toilets. These units were intentionally oversized originally to account for the additional loads that the tenants would install as well. For example, one tenant is planning to install a data center space, and the additional ventilation needs for that area will be accounted for by these units. For the purpose of this report the new AHUs were resized for the existing, permanent load. For actual application, the extra tenant loads should be accounted for.

Results

Table 5.8 Trace™ Energy Consumption Data

	Original Ventilation Scheme		Proposed DOAS Scheme	
Monthly Energy Consumption	Energy, kWh	Cost, £	Energy, kWh	Cost, £
Electric	20,394,152 kWh	£937,840.56	13,608,401 kWh	£626,238.89
Gas	8,288,669 kWh	£14,622.22	1,242,134 kWh	£2,191.11
Water	--	--	--	--
Total Monthly Utility Cost		£952,462.78		£628,430.00
Total Yearly Consumption	69,913,486 kWh		42,136,788 kWh	
Life Cycle Cost		**£17,704,689.24**		**£15,878,842.97**

The new ventilation system was integrated with the existing chiller and boiler plants. The data from the Trace™ simulation is summarized in Table 5.8, with the cost values based on the utility rates noted in Table 5.3. By reducing the size of each air handling unit and replacing the fan coil units with chilled beams the life cycle cost was reduced by 10.31%, saving over 2.7 million kWh annually and £3,888,384.

Table 5.9 Fan Coil versus Chilled Beam First Costs

	Fan Coil Unit			Chilled Beam
	Type 1 - Perimeter	Type 2 - Internal	Type 3 - Lobby	
Cost per Unit	£885.00	£743.00	£743.00	£500.00
No. Units	343	394	22	991
Sub Total	£303,555.00	£292,742.00	£16,346.00	£495,500.00
		Total Cost	**£612,643.00**	**£495,500.00**
		% Savings	**-19.12%**	

*Total Cost denotes first cost excluding installation fees

Table 5.10 AHU First Cost Savings

	Existing AHUs					
	AHU 1	AHU 2	AHU 3	AHU 4	AHU 7	**Total Costs**
Size, L/s	18977	18346	2332.7	3204	1026	
Size, cfm	40041	38710	4922	6760	2165	
Cost per Unit	£85,000.00	£85,000.00	£13,781.00	£13,781.00	£16,700.00	**£214,262.00**

	Proposed AHUs				
	AHU 1	AHU 2	AHU 3+4 (Combined)	AHU 7	
Size, L/s	7644.7	7600.12	518.4	923.5	
Size, cfm	16130	16036	1094	1949	
Cost per Unit	£47,880.00	£47,880.00	£10,845.00	£7,965.00	**£114,570.00**

Tables 5.9 and 5.10 take a look at the savings in First Costs when using reduced Air Handling Units and Chilled Beams versus the existing AHUs with fan coil units. There is a 19% reduction in cost when using a Chilled Beam system versus fan coil units. And there are more significant savings when reducing the Air Handling Units so dramatically, thus reducing the life cycle costs even further.

The benefits of a Dedicated Outdoor Air system are overwhelming for application in the Palestra building, and would be an excellent design alternative. The current constant air volume system with fan coil units isn't terribly different from a pure DOAS, making a future renovation quite feasible.

c. Comparison and Results

Both mechanical design alternatives studied in this report had favorable results to improve both the energy efficiency and economic value of the Palestra Building. The Gas Driven Chiller plant saved over 7 million kWh and 9.54% in Life Cycle costs, while the DOAS design with parallel chilled beams reduced the annual energy consumption by 2.7 million kWh and 9.16% in Life Cycle Costs.

Due to the success of each proposed system, a 'hybrid' design was then simulated in Trace™ as well. This integrated a Dedicated Outdoor Air System and chilled beams with a gas engine driven chiller plant and the existing gas-fired boiler plant. The results of those calculations are summarized in Table 5.11.

Table 5.11 Trace™ Energy Consumption Data

	Original Scheme		Proposed DOAS+Engine Chiller Scheme	
Monthly Energy Consumption	Energy, kWh	Cost, £	Energy, kWh	Cost, £
Electric	20,394,152 kWh	£937,840.56	12,669,017 kWh	£583,102.22
Gas	8,288,669 kWh	£14,622.22	2,770,855 kWh	£4,888.33
Water	--	--	19,061 kL	£14,794.44
Total Monthly Utility Cost		£952,462.78		£602,785.00
Total Yearly Consumption	69,913,486 kWh		40,927,536 kWh	
Life Cycle Cost		**£17,704,689.24**		**£15,899.365.13**

When combined the owners of the Palestra Building could reduce the Life Cycle cost by 10.2% and save over £349,677 a month in energy costs. Over the life span of a building this could be an excellent investment. In addition to the economic benefits there should be improved thermal comfort and humidity control, and opportunities to incorporate new technologies and forms of heat recovery as needed.

VI. Renewable Resource Breadths

The Palestra Building has been under construction for the past 18 months, with a completion date for July 2006. However, the London Development Agency (LDA) has recently signed on as tenants for the fifth and sixth floors. This Agency will be responsible for all of the planning of the 2012 Summer Olympics in London. One of their primary requests has been to install both Solar PV cells and Wind Turbines on the roof with the intention of using any generated power in their office space, and possibly selling any excess energy back to the grid. London was granted the 2012 Olympics due in great part to their platform of a Zero Impact/"Green" design scheme, and the Agency wants to prove it is fluent with these technologies. As of a visit in March of 2006 no one was certain about any details for these plans: how many/large these technologies would be, their locations, or effectiveness. Therefore this report will complete a feasibility study for both technologies to better understand the amount of potential power that can be produced, smart uses for the energy, as well as cost impact of such decisions.

a. Solar Energy Breadth – Photovoltaic (PV) Cells

The mean solar radiation incident on the mainland of the United Kingdom is at best 5 kWh/m^2. The Palestra Building is tall enough relative to the surrounding structures so that there is an unobstructed southern exposure from the roof level, allowing maximum solar gains, as shown in the image to the right. However, the placement of the solar PV cells is crucial to the success of such a system. And unfortunately due to the

Figure 6.1 The Palestra Building super-imposed onto its lot.

timing of this addition to the design, there is little available space on the roof. The total area of the roof is 1236 m^2. Provisions were made for a 200 m^2 array of PV cells facing south.

Calculations

RETScreen International Clean Energy Project Analysis Software, Photovoltaic Project Model was used to create an energy simulation of the array of solar PV panels. The following calculations were based on a solar cell manufactured by BP Solar, BP 5160 S. Physical data coordinating to this model is summarized in Table 6.1.

Table 6.1 PV Cell Data

Model	BP 5160 S
Maximum Nominal Output	160 W
Maximum Panel Voltage	1000 V
Dimensions:	
Length	1596 mm
Width	790 mm
Height	0 mm
Weight	15 kg

Within the 100 m^2 allotted an array of 155 panels can be assembled, adding a total of 2325kg to the roof structure. The Annual Energy Produced by the modules is listed in Table 6.2. The 63 units can deliver over 8,000 kWh per annum. Currently the annual consumption for the space to be occupied by the LDA is 12,711,542 kWh. Therefore 0.16% of the demand can be met by solar energy.

Table 6.2 Estimated Annual Energy Produced

Specific Yield	102.4 kWh/m^2
Overall PV System Efficiency	10.20%
Renewable Energy Delivered	19,995 kWh

Cost Analysis

The financial summary for an investment in solar PV cells for the Palestra Building is summarized in Table 6.3.

Table 6.3 Cost Summary

Total Initial Cost	£205,303.00
Total Annual Cost	£ 880.00
Total Annual Savings	£31,152.00
Simple Payback	9.1 years
Years to Positive Cash Flow	6 years
Net Present Value (NPV)	£125,778.00
Annual Life Cycle Cost Savings	£12,805.00

The initial cost for the system is £205,000, with annual savings of £31,152.00. However the simple payback period is 9 years, with no positive cash flow until year 6. That length is quite long compared to what most investors would consider a strong investment where less than 3 years for a return is typical. All additional data, calculations, and specification sheets can be found in Appendix VI.

b. Wind Energy Breadth – Wind Turbine

The challenges that faced the implementation of a solar system on the roof of the Palestra Building hold true for the wind system as well. Although with wind turbines there is the additional sensitivity of height. You must be careful not to create an imbalance in the frame of the structure, or a 'top heavy' scenario. Recently the SWIFT Rooftop Wind Energy System™ has been developed and implemented in residential locations in Scotland. It is a modified wind system for smaller buildings, with a maximum output of 1.5kW based on a wind speed of 12.5 m/s. And at that rate it can displace up to 1.4 tonnes of CO_2 per year, making it easier to meet new building emission regulations.

Figure 6.2 Residential Application of SWIFT™ technology.

This product has recently received the support of the Scottish government, and is the only product of its type that has been approved for government grants making it possible for any person or company to afford renewable technologies. The micro-turbines are set for mass production in the coming months which will drive the price from the current £3500 to £1500 per unit. And much of the remaining sum will be eligible for a grant as well, bring the first costs down to practically nothing.

Figure 6.3 Commercial Application of SWIFT™ technology.

Building Regulations in the UK are beginning to require that every building provide at least 10% of its energy through renewable resources or Combined Heat and Power (CHP). In an area with high enough wind speeds, that percentage could easily be met with this wind technology.

Table 6.4 contains the technical data for each micro wind turbine.

Table 6.4 Rooftop Wind Turbine Specifications

Manufacturer	SWIFT™
Rated Output @ 12.5 m/s	1.5 kW
Output @ 4.6 m/s (London)	60 W
CO2 Displacement	1.4 tonnes per year
Turbine	5 blade HAWT wind turbine
Rotor Diameter	2.12 m
Weight	95 kg

Figure 6.4 shows the Power Curve for the Micro Turbine. As you can see its power output is highest between 12 and 20 m/s. Unfortunately the average wind speed in London is 4.6 m/s, resulting in 60W output per unit. Due to the small amount of power available it is unlikely that wind energy would be an efficient means of energy production for the Palestra Building. However because the National London Agency, a tenant in the Palestra Building, is set on installing wind technology regardless of the efficiency, it is beneficial to complete an analysis to see how the amount of energy gained may be effectively used.

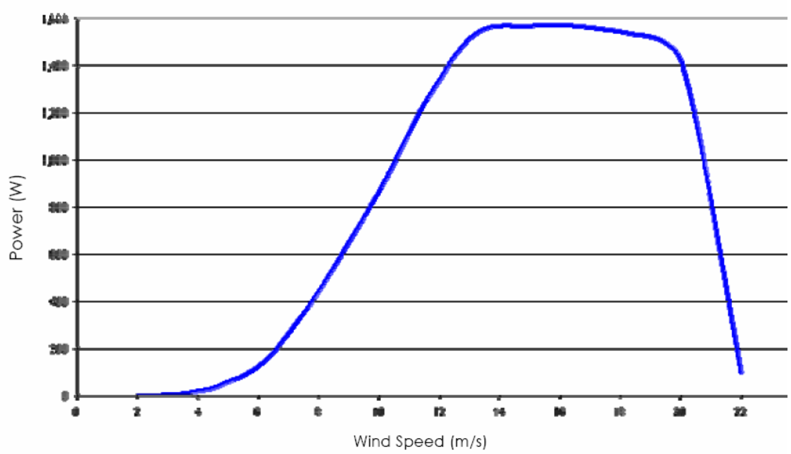


Figure 6.4 SWIFT™ Wind Turbine Power Curve

Table 6.5 Wind Turbine Costs

No. Units	10
Clearance Per Unit	2.12 m
Area Required	50 m^2
Total Weight	950 kg
Initial Investment	£15,000
Total Power Output	600 W
Annual Savings	120 kWh

Based on the limited amount of free area on the roof, the light weight of each wind turbine (95kg), and low power output from each, and the relatively low first costs, 10 units were assumed to be a reasonable numbers of fans for the system. Table 6.5 outlines the assumptions made for the Cost Analysis.

Payback Period

$$Payback\ Period\ (in\ years) = \frac{Initial\ Investment}{Annual\ Savings\ (Cash\ Flow)}$$

Assuming annual savings at peak electrical rate:

Annual Savings = 120 kWh * 4.592 p/kWh = 551.04p = £5.51

$$Payback\ Period = \frac{£15{,}000}{£5.51} = \mathbf{2722\ years}$$

The hypothesis that the wind technology would have little to no value for the Palestra Building is correct. With such a large payback period it would never be economical as long as the average wind speed for the area is so low. It is strongly suggested that wind technology not be installed, and invest the additional spaces and finances to increasing the efficiency of the Solar PV system which has much more potential to produce significant annual savings.

The only time wind turbines would still be a smart investment is if a Federal Grant covered all or most of the first costs for the turbine units. In that case all energy produced would be 'free' and while still not a useful amount of energy, it wouldn't be at a deficit to the project cost.

VII. Acoustical Breadth – Mechanical Noise Impact on Community

When altering the mechanical equipment that is place outdoors (i.e. roof level) it is important to understand the acoustical effects of these changes to ensure that neighboring buildings are not affected by the additional noise, if any.

An increase in acoustical levels is expected when switching from electric air-cooled chiller to IC engine driven chillers because of the nature of the machines. However, if there is a dramatic increase in sound pressure levels then measures will need to be taken to install acoustical barriers.

The following are the calculations used to determine the community's reaction to the existing chiller plant in comparison to the proposed engine driven chiller plant.

Step 1: Plot decibel (dB) levels for the sound emitter on the Composite Noise Rating (CNR) curve. The CNR rating is the lowest CNR curve not exceeded.

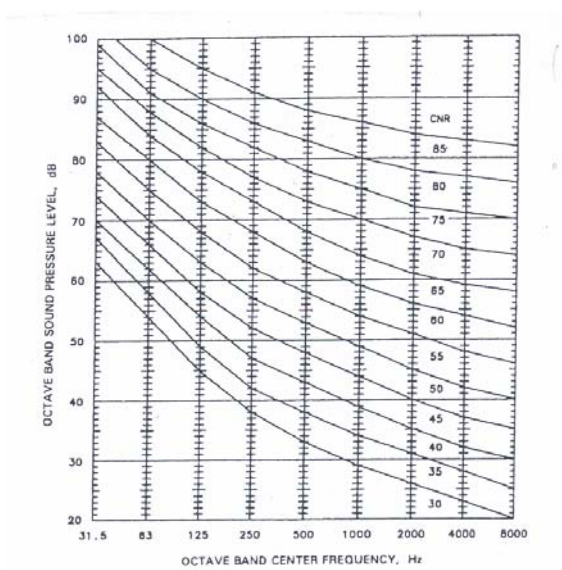


Figure 7.1 Composite Noise Rating Curves

Step 2: Correct for Background Noise

Condition	Background Correction Number
Nighttime, rural; no nearby traffic of concern	+15
Daytime, rural; no nearby traffic of concern	+10
Nighttime, suburban; no nearby traffic of concern	+10
Daytime, suburban; no nearby traffic of concern	+5
Nighttime, urban; no nearby traffic of concern	+5
Daytime, urban; no nearby traffic of concern	0
Nighttime, business or commercial area	0
Daytime, business or commercial area	−5
Nighttime, industrial or manufacturing area	−5
Daytime, industrial or manufacturing area	−10
Within 90 m of intermittent light traffic	0
Within 90 m of continuous light traffic	−5
Within 90 m of continuous medium-density traffic	−10
Within 90 m of continuous heavy-density traffic	−15
90 to 300 m from intermittent light traffic	+5
90 to 300 m from continuous light traffic	0
90 to 300 m from continuous medium-density traffic	−5
90 to 300 m from continuous heavy-density traffic	−10
300 to 600 m from intermittent light traffic	+10
300 to 600 m from continuous light traffic	+5
300 to 600 m from continuous heavy-density traffic	−5
600 to 1200 m from intermittent light traffic	+15
600 to 1200 m from continuous light traffic	+10
600 to 1200 m from continuous medium-density traffic	+5
600 to 1200 m from continuous heavy-density traffic	0

Figure 7.2 Correction Values for Possible Background Noise

Step 3: Correct for other factors.

Correction for time-of-day and seasonal factors *(for full-time operation, total correction is 0)*	
Daytime only	−5
Nighttime (2200 to 0700 hrs)	0
Winter only	−5
Winter and summer	0
Correction for intermittency *(ratio of source "on" time to reference time period)*	
1.00 to 0.57	0
0.56 to 0.18	−5
0.17 to 0.06	−10
0.05 to 0.018	−15
0.017 to 0.0057	−20
0.0057 to 0.0018	−25
Correction for character of noise	
Noise is very low frequency (peak level at 1/1 octave center frequency of 125 Hz or lower)	+5
Noise contains tonal components	+5
Impulsive sound	+5
Correction for previous exposure and community attitude	
No prior exposure	+5
Some previous exposure but poor community relations	+5
Some previous exposure and good community relations	0
Considerable previous exposure and good community relations	−5

Figure 7.3 Correction Values for Other Factors

Step 4: Determine probable community reaction.

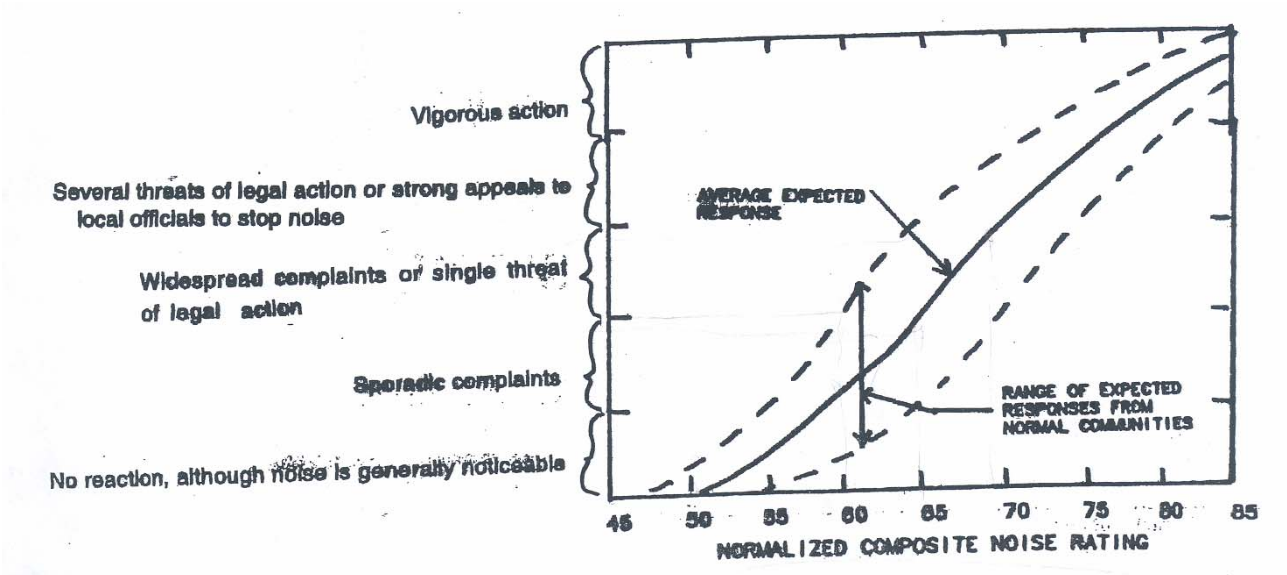


Figure 7.4 Community Reaction Graph

Tables 7.1 and 7.2 outline the acoustic calculations for both the existing conditions and the proposed engine system.

Table 7.1 Existing HVAC Acoustics

Composite Noise Rating (CNR)

Existing Electric Chillers

Freq	dBA @ 1m	dBA-dB conversion	**dB**
63	57	-26.2	**31**
125	71	-16.1	**55**
250	70	-8.6	**61**
500	72	-3.2	**69**
1000	66	0	**66**
2000	62	1.2	**63**
4000	55	1	**56**
8000	46	-1.1	**45**
		Uncorrected CNR = 70	

Background Noise Correction Factors

90-300m from continuous heavy density traffic = -10

Time of Day

Daytime Only = -5

Winter and Summer = 0

Intermittency

1.00-0.57 = 0

Character of Noise

None

Previous Exposure and Community Attitude

Considerable previous exposure and good community relations = -5

Corrected CNR **50**

REACTION: No reaction, although noise is generally noticeable

Table 7.2 Proposed HVAC Acoustics

Composite Noise Rating (CNR)

Proposed Engine Driven Chiller

Freq	dB @ 1m
63	72
125	78
250	84
500	89
1000	86
2000	80
4000	72
8000	64

Uncorrected CNR = 85

Background Noise Correction Factors

90-300m from continuous heavy density traffic = -10

Time of Day

Daytime Only = -5

Winter and Summer = 0

Intermittency

1.00-0.57 = 0

Character of Noise

None

Previous Exposure and Community Attitude

Considerable previous exposure and good community relations = -5

Corrected CNR **65**

REACTION: Sporadic Complaints

Tables 7.1 and 7.2 also summarize the results of the Composite Noise Rating for the electric chiller scheme as well as the IC engine driven chiller plant. The community's reaction to the existing design is "No reaction, although noise is generally noticeable," while the new plant has a reaction of "Sporadic Complaints." The Palestra Building has a large advantage because of its location with respect to noise because it is such a high traffic area with the Underground Station, the above ground trains, and a busy intersection. The members of the community are somewhat desensitized to the additional noise created.

Figure 7.5 View of High Traffic Areas from 7th Floor

VIII. Summary of Results and Conclusion

Studying the impact of a gas driven chiller plant with a Dedicated Outdoor Air System has proven to be a successful proposal. The seven existing air-cooled electric chillers were replaced with five gas engine driven chillers to take advantage of additional heat recovery opportunities as well as the lower cost of natural gas in the UK. Each air handling unit was also resized to meet only the fresh air requirements for the spaces each serves, and installed with an enthalpy wheel for latent heat recovery. To meet the entire sensible load through out the building a parallel chilled beam system was also installed. When both systems are integrated with the existing boiler plant the Life Cycle costs were found to decrease by over 9%, while also decreasing annual energy consumption by 29 million kWh which is a significant financial and environmental impact. In addition the acoustic levels of the new equipment on the roof was analyzed, finding only a slight increase in the community's reaction, but nothing great enough to warrant additional acoustical barriers at this time.

The first tenant obtained for the Palestra Building was the London Development Agency, which is the committee responsible for the planning of the 2012 Olympics in London. Because they promoted 'Green' design in their bid for the Olympics, they want to install 'Green' technologies in the form of Solar PV panels and Wind Turbines on the roof essentially to show that they implement the ideas they promote, but with little regard for the actual efficiency of these systems. The construction of the Palestra Building is set to be completed during the summer of 2006, four months from now and the designs for these systems have yet to be confirmed. After analyzing the possibilities for each design with respect to the existing roof top configuration it was concluded that more than 100 m^2 of solar PV panels would be needed to create a system with a payback within 4 years. And due to the extremely low average wind speed in London at 4.6 m/s, even the most advanced rooftop wind turbine would be unable to produce more than 60 W of energy per unit. Thus it is recommended that the plans for installing wind turbines be abandoned, using the funding to improve the Solar design.

The data collected is very valuable for the engineers, owners, and project managers for insight into the effects of design alternatives as well as to serve as a reference on future projects. Hopefully the results of the Solar and Wind energy studies will be taken into account when finalizing these design schemes.

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APPENDIX A:
Existing Conditions – Internal Loads

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
Volume of infiltration	7.5	m^3/s
Thermal capacity of air	1200	J/m3.K
Total Infiltration load	**225000**	**W**

Indexes	
Building Floor height	3.6
Air changes per hour	0.23

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**
Spare capacity	10%	
Pre-heat period	32%	
Installed Heating Load	**1,796**	**kW**

Indexes	
Building Floor area	26677
Load per m2 (W/m^2)	67.3

Breakdown of cooling loads

	BH proposed Brief	
Internal Cooling Load		
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 B:
Chiller Optimization Data

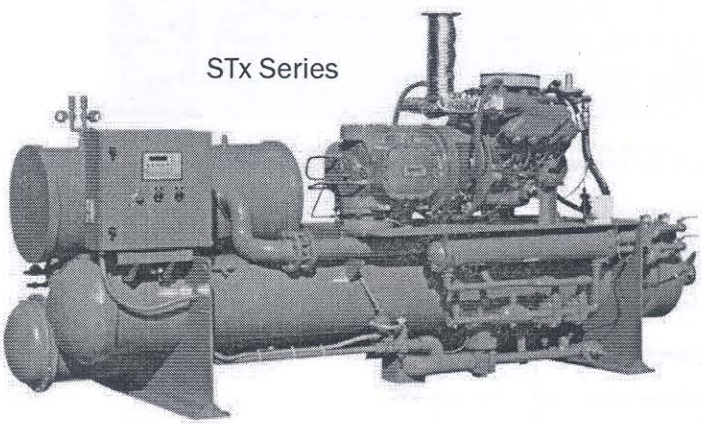
TECOCHILL® Gas Engine Driven Chillers

Water-Cooled Models
150 Tons to 400 Tons

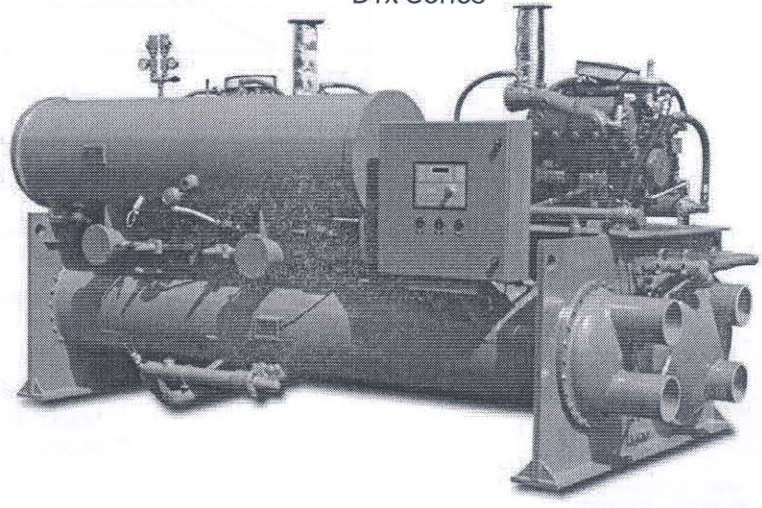
Key Features & Options

- Non-ozone depleting HFC-134a
- TecoDrive 7400™ Natural Gas Engine
- Single Screw Balanced Action Compressor
- High Efficiency Flooded Evaporator
- IPLV's Exceeding 2.5
- Footprint equivalent to electric chillers
- Variable engine speed operation for excellent part load performance and longer life
- TecoNET™ Microprocessor-based Control System with precise PID Control for fully automatic operation, continuous system monitoring, digital display, fault diagnostics, and tie-in to an energy management system
- Remote Monitoring and Control System (RMCS) that permits remote real-time monitoring, data acquisition, and system control by telephone
- ETL Listed

STx Series



DTx Series

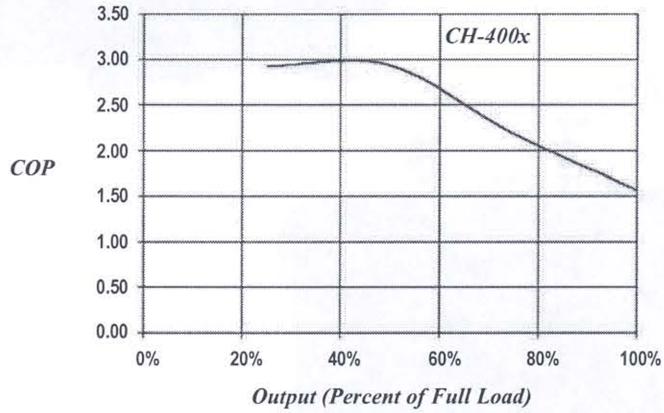


WATER-COOLED MODELS

	STx Series		DTx Series		
	CH-150x	CH-200x	CH-300x	CH-350x	CH-400x
Full Load Rating [tons]	150	200	300	350	400
IPLV COP[4]	2.6	2.6	2.6	2.6	2.6
Full Load COP	1.7	1.6	1.7	1.7	1.6
COP with Engine Heat Recovery	2.1	1.9	2.0	2.0	1.9
Fuel Consumption [MBtu/hr @ HHV 1020 Btu/scf]	1,032	1,526	2,157	2,529	3,052
Fuel Consumption [scfh]	1,012	1,496	2,115	2,479	2,992
Fuel Pressure [in. wc, 27.703 in. wc = 1 psig]	7-28	13-28	7-28	13-28	13-28
Available Engine Heat [MBtu/hr]	323	480	675	799	960
Maximum Supply Temperature [°F]	201	212	202	207	212
WATER SYSTEMS					
Chilled Water Flow [GPM]	360	480	720	840	960
Chilled Water Pressure Drop @ Rated Flow [ft]	9.1	16.2	18.2	9.6	12.6
Total Cooling Tower Flow [GPM]	490	640	980	1,130	1,280
—Flow To Condenser Only [GPM]	450	600	900	1,050	1,200
—Flow To Dump HX Only [GPM]	40	40	80	80	80
Condenser Pressure Drop @ Rated Flow [ft]	13.0	23.1	12.9	14.1	18.1
Cooling Tower Heat Rejection [MBtu/hr]	2,418	3,473	5,376	6.136	6,946
ELECTRICAL REQUIREMENT					
Voltage Requirement	208-230, 50/60 Hz		208-230, 50/60 Hz		
Electrical Service	Single Phase with Neutral		Single Phase with Neutral		
Amperage Rating	30		40		
Parasitic Power Requirement [kW]	2.2		2.7		
ACOUSTIC LEVELS[5] [dBa @ 3 ft]					
—with Enclosure	88	92	88	89	92
—without Enclosure	95	99	95	96	99
Refrigerant	HFC-134a		HFC-134a		
DIMENSIONAL DATA					
Length	13'10"		14'3"		
Width	4'4"		7'0"		
Height	6'9"		7'7"		
WEIGHTS					
Rigging Weight [lb]	10,450		24,675		
Operational Weight [lb]	11,250		28,175		
DRIVELINE					
Engine	TecoDrive 7400		TecoDrive 7400 (2)		
Compressor	J&E Hall HS2024GED		J&E Hall HS2024GED (2)		

NOTES:
1. *Specifications subject to change without notice, all specifications are ± 5%.*
2. *COP ratings are based upon Fuel Highter Heating Value (HHV) @ 1020 BTU/SCF*

TYPICAL TECOCHILL PART-LOAD PERFORMANCE



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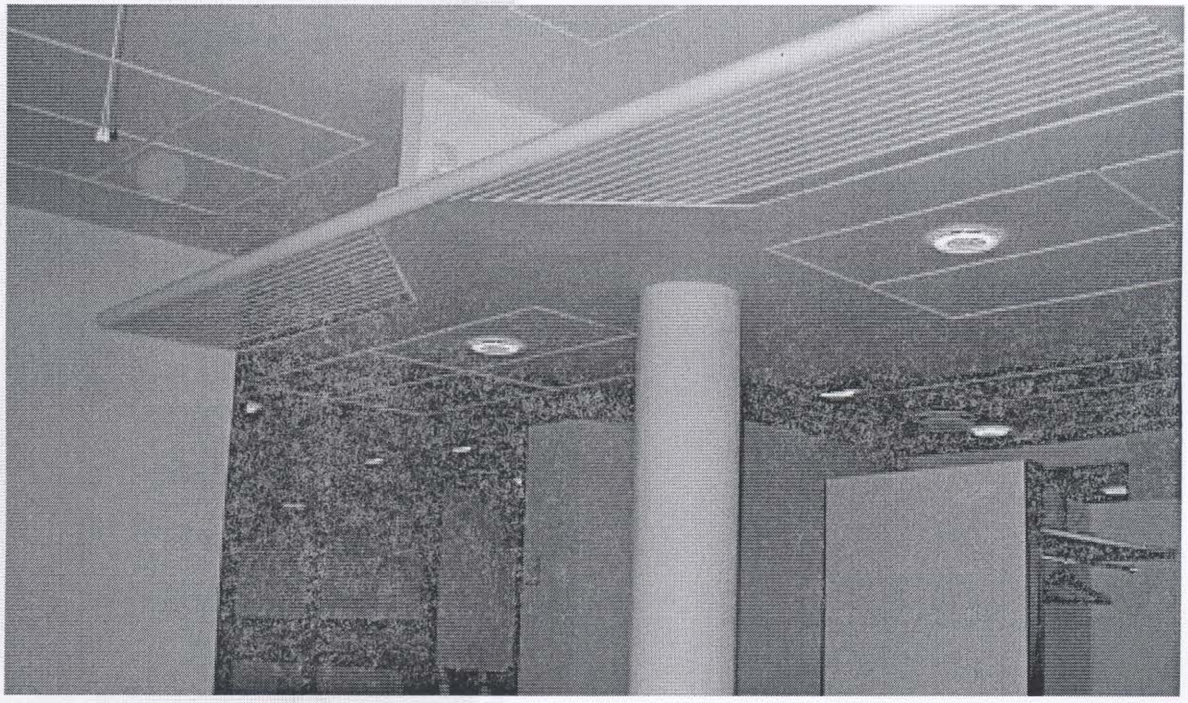
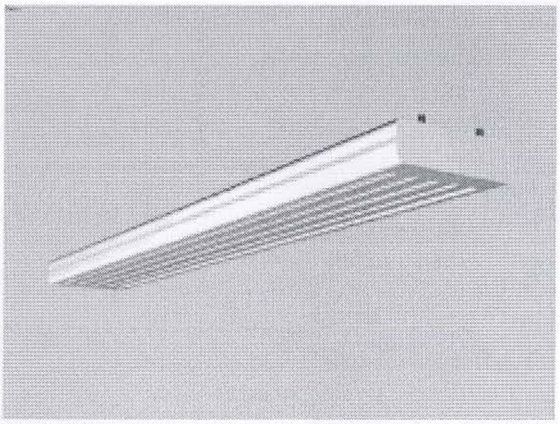
APPENDIX C:
DOAS Data

CLL -Cooling Panel with Radiant and Convective Cooling





- The CLL is a ceiling-mounted cooling and/or heating panel.
- Heat is absorbed by radiant and convective cooling.
- The unit is architecturally aesthetic and is easy to clean.
- Designed to be flush mounted within a suspended ceiling or fully exposed.
- The beam is suitable for spaces with a high cooling requirement, low humidity and ventilation loads.
- The CLL is suitable for a large range of building applications where requirement for good quality environmental conditions and individual space control is important.
- The CLL is available with factory-fitted 2- or 3-way control valves.
- Typically the CLL is used in offices, conference rooms and hotel rooms.

QUICK DATA

Cooling capacity	275 W/m2 (ΔT=9 °C)
Length	1100 - 4100 mm
Width	280,380,480,580,780 and 980 mm
Height	80 mm

Halton

FUNCTION

The excess heat in the room is absorbed by both radiation and convection.

The CLL surfaces are cooled by water circulated in the unit. The cooled surfaces absorb heat from warm room surfaces and people. The radiant effect is as high as 25% of total cooling capacity.

The beam surfaces create circulation of room air with very low velocities. The airflow rate through the cooled beam varies with the cooling load, thus creating a partly self-regulating system.

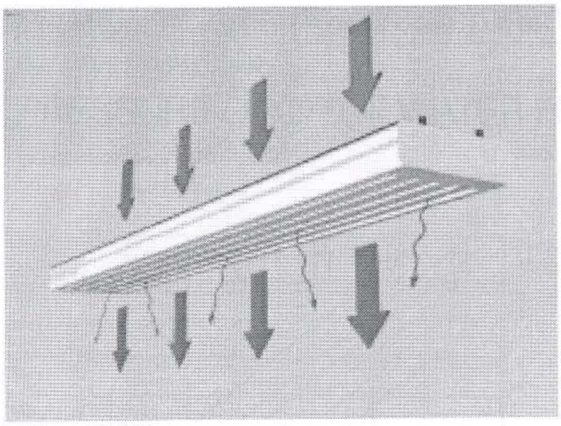
The cooling output is controlled using the room thermostat and valve to change water flow rate.

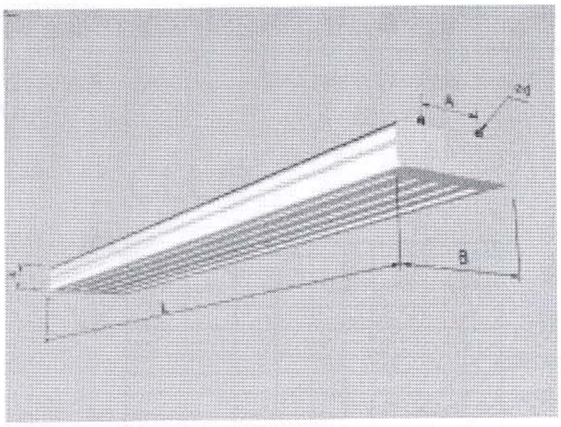
MATERIAL AND FINISHING

The CLL is manufactured of extruded aluminium, white painted, with water pipes of copper. All parts are easily recyclable.

ACCESSORIES

- Factory fitted 2-way control valve(CV/CLL-2)
- Factory fitted 3-way control valve(CV/CLL-3)
- Flexible connecting pipes (FT)
- Pipe connection straight (CP/CLL-S)
- Pipe connection up (CP/CLL-U)
- Factory fitted built-in control valve and thermostat (TV/CLL-O)
- External thermostats; capillary type (T1)
- External thermostats, electronic 24V (T2)
- External thermostats, electronic 240V (T3)
- Balancing and shut-off valve (BV)





DIMENSIONS

B	H	d	A	L
280	80	12	140	4100
380	80	12	240	1100, 2100, 4100
480	80	12	340	1100, 2100, 4100
580	80	12	440	1100, 2100, 4100
780	80	12	640	1100, 2100, 4100
980	80	12	840	1100, 2100

COOLING CAPACITY

	Pw (W)						
	ΔT (°C)						
	6	7	8	9	10	11	12
CLL 280-4100	196	230	276	322	368	403	449
CLL 380-1100	71	84	101	118	134	147	164
CLL 380-2100	136	160	192	224	256	280	312
CLL 380-4100	265	312	374	437	499	546	608
CLL 480-1100	90	106	127	148	170	186	207
CLL 480-2100	172	202	242	283	323	354	394
CLL 480-4100	335	394	473	552	630	690	768
CLL 580-1100	109	128	154	179	205	224	250
CLL 580-2100	207	244	293	342	390	427	476
CLL 580-4100	405	476	571	666	762	833	928
CLL 780-1100	146	172	206	241	275	301	335
CLL 780-2100	279	328	394	459	525	574	640
CLL 780-4100	544	640	768	896	1024	1120	1248
CLL 980-1100	184	216	259	302	346	378	421
CLL 980-2100	350	412	494	577	659	721	803

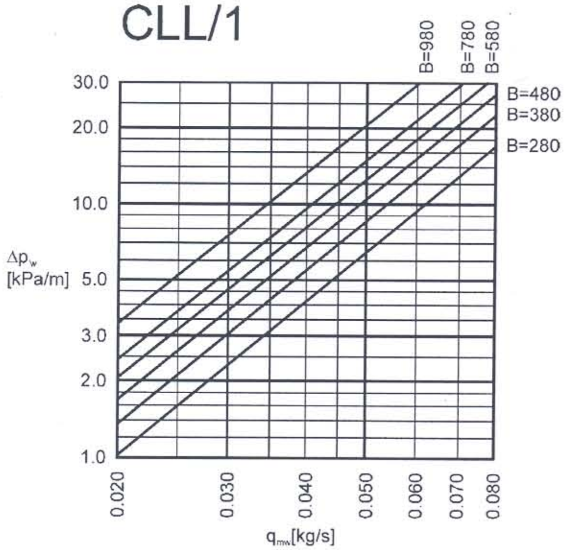
CORRECTION FACTOR -k- FOR OTHER WATER FLOW RATES

q_{mw} (kg/s)	0,015	0,02	0,025	0,03	0,035	0,04	0,045	0,05	0,055	0,06	0,08
k_c (CLL)	0,79	0,83	0,86	0,88	0,91	0,92	0,94	0,96	0,97	0,98	0

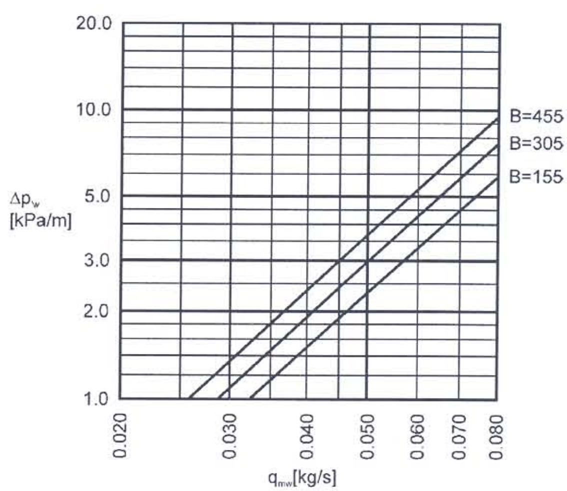
Pw = Pw(0,08kg/s) x k_c.

PRESSURE DROP OF WATER FLOW

CLL/1



CLL/2



NOTATIONS

Cooling capacity is measured according NVVS 078

ΔT	temperature difference Tr-(Tw1+Tw2)/2
Pw	water cooling capacity
qmw	water mass flow rate
k_c (CLL)	correction factor for other water flow rates, cooling
Δp_w	pressure drop of water flow/length of device

Halton

SPECIFICATION

The static cooling panel shall be the Halton type CLL. The unit shall consist of heat transfer surfaces, with integrated water pipework and open slots for the air to pass through.

The cooling/heating surfaces shall be manufactured from aluminium profiles. The water circuit shall be constructed of copper pipes nominal 12 mm outside diameter. The water circuit maximum working pressure is 1,0 MPa. All the joints shall be fully soldered and factory pressure tested.

PRODUCT CODE

CLL /S -B -L

Total length
1100,2100,4100

Beam width
280,380,480,580,780,980

Nbr. of water circuit
1=one water circuit
2=two -"- (for 580,780,980)

Specifics and accessories

AC=

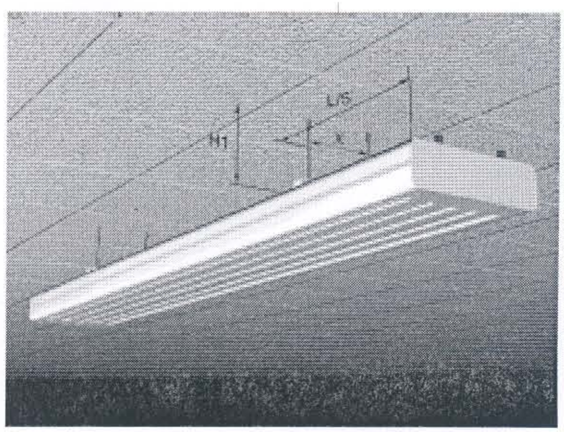
Accessories
- CV/CLL-2=Factory fitted 2-way control valve
- CV/CLL-3=Factory fitted 3-way control valve
- FT=Flexible connecting pipes
- CP/CLL-S=Pipe connection straight
- CP/CLL-U=Pipe connection up
- TV/CLL-O=Built-in control valve and thermostat
- T1=External thermostats,capillary type
- T2=External thermostats, electronic 24V
- T3=External thermostats,electronic 240V
- BV=Balancing and shut-off valve

Example

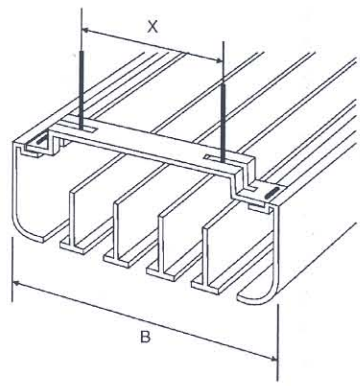
CLL/1-480-2100;AC=CP/CLL-S,BV
CLL/2-780-1100;AC=BV

INSTALLATION

The cooled beam CLL can be installed flush with a suspended ceiling or fully exposed. In the case of flush installation, openings for return room air must be provided. To secure convection, the beam should be mounted so that the distance to the ceiling is 0,25 x the width of the beam when installed away from wall surfaces, or 0,35 x beam width when installed close to partitioning walls.



Each beam is fixed to the ceiling with expansion anchors and threaded drop rods (by others). On the beam, two (or three for 4100 mm) mounting brackets are fixed approx. 1/5 from the end of the beam (and in the middle on 4100 mm). The exact position of the brackets is adjusted according to the rod's position and the beam is easily adjusted both horizontally and vertically. Mounting brackets are supplied as standard in the package. The installation company must supply threaded rods and expansion anchors.



SERVICE

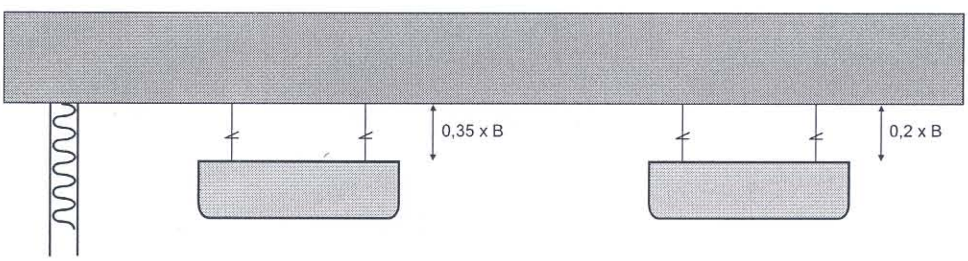
The CLL requires little maintenance. It may be necessary to clean the cooling profiles after 3 -5 years, depending on room conditions and air quality. The cooling profiles are easy to clean with a vacuum cleaner, without the need to open or dismount the beam.

ADJUSTMENT

Commissioning of the beam system is carried out in the conventional way.

· Fill up and flush the main pipelines.
· Fill up and vent the beam circuits.
· Adjust correct water flows with balancing valves for all main lines
· Adjust correct water flows for all beams.

B	X
280	100
380	200
480	300
580	400
780	600
980	800



Picture 1. Installation - distance from the ceiling

APPENDIX D: Trace Output

Existing Systems Energy Simulation

EQUIPMENT ENERGY CONSUMPTION
By ae

Alternative: 1 Palestra Building

Equipment - Utility		------- Monthly Consumption -------												
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Lights														
	Electric (kWh)	135,459.5	122,510.0	145,343.4	129,495.7	140,401.4	139,379.6	130,517.6	145,343.4	129,495.7	140,401.4	134,437.6	130,517.6	1,623,302.8
	Peak (kW)	439.7	439.7	439.7	439.7	439.7	439.7	439.7	439.7	439.7	439.7	439.7	439.7	439.7
MISC LD														
	Electric (kWh)	234,034.4	211,696.4	253,279.4	223,381.2	243,657.1	242,625.8	224,412.1	253,279.4	223,381.3	243,657.1	233,003.5	224,412.1	2,810,820.0
	Peak (kW)	816.2	816.2	816.2	816.2	816.2	816.2	816.2	816.2	816.2	816.2	816.2	816.2	816.2
AHU 1														
Eq4371 - Fan coil supply fan (Main Clg Fan)														
	Electric (kWh)	266,006.9	254,985.8	306,652.6	263,462.2	336,715.3	345,809.9	404,881.2	433,306.1	344,123.8	313,433.8	266,362.5	251,983.3	3,787,723.3
	Peak (kW)	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,500.0	1,500.0	1,500.0	1,425.0	1,425.0	1,425.0	1,425.0	1,500.0
AHU 2														
Eq4371 - Fan coil supply fan (Main Clg Fan)														
	Electric (kWh)	251,393.2	229,756.5	278,262.3	243,554.5	272,396.3	273,698.9	263,497.0	294,199.0	251,853.8	286,334.8	252,604.0	240,197.4	3,137,747.8
	Peak (kW)	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0
AHU 3														
Eq4372 - Unit vent supply fan (Main Clg Fan)														
	Electric (kWh)	5,364.1	3,898.3	4,612.9	3,854.4	2,920.2	2,904.0	2,902.6	3,037.7	2,695.7	3,074.8	4,348.7	4,114.1	43,727.5
	Peak (kW)	55.0	55.0	55.0	55.0	38.5	38.5	40.2	38.5	38.5	38.5	55.0	55.0	55.0
AHU 4														
Eq4372 - Unit vent supply fan (Main Clg Fan)														
	Electric (kWh)	6,044.0	4,274.3	4,922.9	3,904.2	2,929.2	2,912.6	3,419.0	3,066.5	2,727.9	3,182.5	4,816.4	4,466.5	46,666.0
	Peak (kW)	55.0	55.0	55.0	55.0	38.5	38.5	55.0	38.5	38.5	38.5	55.0	55.0	55.0
AHU 7														

EQUIPMENT ENERGY CONSUMPTION
By ae

Alternative: 1 Palestra Building

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Consumption -------								
AHU 7													
Eq4371 - Fan coil supply fan (Main Clg Fan)													
Electric (kWh)	76,020.0	68,780.0	83,260.0	72,400.0	79,640.0	79,640.0	72,400.0	83,260.0	72,400.0	79,640.0	76,020.0	72,400.0	915,860.0
Peak (kW)	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0
Cpl 1: CHILLERS													
Chiller 2 (Cooling Equipment)													
Electric (kWh)	225.8	170.5	223.3	414.3	1,479.8	2,236.1	17,037.9	5,798.3	2,895.4	1,269.4	266.1	250.4	32,267.2
Peak (kW)	30.5	30.4	30.3	41.3	41.3	41.3	148.6	118.7	84.1	41.3	34.2	41.3	148.6
Eq5221 - Condenser fan													
Electric (kWh)	829.9	747.5	944.4	941.5	2,252.7	2,138.4	4,785.9	4,138.8	2,750.6	1,381.3	852.9	796.1	22,559.8
Peak (kW)	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2
Eq5001 - Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	11.0	5.5	7.3	14.7	132.1	181.6	238.4	232.0	167.8	134.8	11.0	8.3	1,144.4
Peak (kW)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Eq5011 - Cnst vol cnd water pump (Misc Accessory Equipment)													
Electric (kWh)	96.8	48.4	64.6	129.1	1,161.9	1,597.6	2,097.8	2,041.3	1,476.5	1,186.1	96.8	72.6	10,069.4
Peak (kW)	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
Eq5302 - Cntl panel & interlocks (Misc Accessory Equipment)													
Electric (kWh)	1.2	0.6	0.8	1.6	14.4	19.8	26.0	25.3	18.3	14.7	1.2	0.9	124.8
Peak (kW)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Chiller 3 (Cooling Equipment)													
Electric (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	5,856.1	0.0	0.0	0.0	0.0	0.0	5,856.1
Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	148.6	118.7	0.0	0.0	0.0	0.0	148.6
Eq5221 - Condenser fan													
Electric (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	673.1	0.0	0.0	0.0	0.0	0.0	673.1
Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	16.1	13.7	0.0	0.0	0.0	0.0	16.1
Eq5001 - Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	55.0	0.0	0.0	0.0	0.0	0.0	55.0
Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.9	0.0	0.0	0.0	0.0	0.9

EQUIPMENT ENERGY CONSUMPTION
By ae

Alternative: 1 Palestra Building

Equipment - Utility		------- Monthly Consumption -------												
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Cpl 1: CHILLERS														
Eq5012 - Cnst vol cnd water pump (Misc Accessory Equipment)														
	Electric (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	581.3	0.0	0.0	0.0	0.0	0.0	581.3
	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	9.7	9.7	0.0	0.0	0.0	0.0	9.7
Eq5302 - Cntl panel & interlocks (Misc Accessory Equipment)														
	Electric (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	6.0
	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1
Chiller 4 (Cooling Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	148.5	0.0	0.0	0.0	0.0	0.0	148.5
Eq5221 - Condenser fan														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	16.1	0.0	0.0	0.0	0.0	0.0	16.1
Eq5001 - Cnst vol chill water pump (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.9
Eq5011 - Cnst vol cnd water pump (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	8.1	0.0	0.0	0.0	0.0	0.0	8.1
Eq5302 - Cntl panel & interlocks (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Chiller 5 (Cooling Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	148.5	0.0	0.0	0.0	0.0	0.0	148.5
Eq5221 - Condenser fan														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	16.1	0.0	0.0	0.0	0.0	0.0	16.1
Eq5001 - Cnst vol chill water pump (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.9
Eq5011 - Cnst vol cnd water pump (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	8.1	0.0	0.0	0.0	0.0	0.0	8.1
Eq5302 - Cntl panel & interlocks (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Chiller 6 (Cooling Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	148.5	0.0	0.0	0.0	0.0	0.0	148.5
Eq5221 - Condenser fan														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	16.1	0.0	0.0	0.0	0.0	0.0	16.1

EQUIPMENT ENERGY CONSUMPTION

By ae

Alternative: 1 Palestra Building

Equipment - Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Cpl 1: CHILLERS														
Eq5001 - Cnst vol chill water pump (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.9
Eq5302 - Cntl panel & interlocks (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Chiller 7 (Cooling Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	134.9	0.0	0.0	0.0	0.0	0.0	134.9
Eq5221 - Condenser fan														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	14.8	0.0	0.0	0.0	0.0	0.0	14.8
Eq5001 - Cnst vol chill water pump (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.9
Eq5302 - Cntl panel & interlocks (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Chiller 1 (Cooling Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	135.0	0.0	0.0	0.0	0.0	0.0	135.0
Eq5221 - Condenser fan														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	14.8	0.0	0.0	0.0	0.0	0.0	14.8
Eq5001 - Cnst vol chill water pump (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.9
Eq5302 - Cntl panel & interlocks (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Hpl 1: BOILERS														
Boiler 1 (Heating Equipment)														
	Gas (kWh)	287,220.4	281,241.8	338,255.3	240,878.6	167,499.1	165,143.7	51,019.5	98,907.3	102,842.2	162,823.1	262,783.5	234,140.6	2,392,755.3
	Peak (kW)	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6
Eq5020 - Heating water circ pump (Misc Accessory Equipment)														
	Electric (kWh)	294,450.0	268,125.0	340,275.0	253,500.0	196,950.0	193,050.0	63,375.0	123,825.0	122,850.0	214,500.0	286,650.0	273,000.0	2,630,550.0
	Peak (kW)	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0

EQUIPMENT ENERGY CONSUMPTION

By ae

Alternative: 1 Palestra Building

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Consumption -------								
Hpl 1: BOILERS													
Eq5240 - Boiler forced draft fan (Misc Accessory Equipment)													
Electric (kWh)	824.6	750.9	952.9	709.9	551.5	540.6	177.5	346.8	344.0	600.7	802.7	764.5	7,366.6
Peak (kW)	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Eq5307 - Boiler cntl panel & inter (Misc Accessory Equipment)													
Electric (kWh)	151.0	137.5	174.5	130.0	101.0	99.0	32.5	63.5	63.0	110.0	147.0	140.0	1,349.0
Peak (kW)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Boiler 2 (Heating Equipment)													
Gas (kWh)	278,048.9	265,365.8	321,951.3	232,376.6	139,441.6	113,490.8	34,944.8	74,469.3	76,375.6	138,526.9	237,073.3	220,487.8	2,132,552.8
Peak (kW)	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6
Eq5020 - Heating water circ pump (Misc Accessory Equipment)													
Electric (kWh)	249,600.0	222,300.0	246,675.0	175,500.0	128,700.0	111,150.0	43,875.0	93,600.0	86,775.0	128,700.0	216,450.0	200,850.0	1,904,175.0
Peak (kW)	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0
Eq5240 - Boiler forced draft fan (Misc Accessory Equipment)													
Electric (kWh)	699.0	622.5	690.8	491.5	360.4	311.3	122.9	262.1	243.0	360.4	606.2	562.5	5,332.5
Peak (kW)	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Eq5307 - Boiler cntl panel & inter (Misc Accessory Equipment)													
Electric (kWh)	128.0	114.0	126.5	90.0	66.0	57.0	22.5	48.0	44.5	66.0	111.0	103.0	976.5
Peak (kW)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Boiler 3 (Heating Equipment)													
Gas (kWh)	268,825.0	256,255.0	291,909.8	218,536.6	116,359.2	111,219.5	19,512.2	35,386.3	60,698.7	115,316.5	237,073.3	220,487.8	1,951,579.8
Peak (kW)	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6
Eq5020 - Heating water circ pump (Misc Accessory Equipment)													
Electric (kWh)	249,600.0	222,300.0	228,150.0	159,900.0	111,150.0	111,150.0	19,500.0	48,750.0	67,275.0	128,700.0	216,450.0	200,850.0	1,763,775.0
Peak (kW)	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0
Eq5240 - Boiler forced draft fan (Misc Accessory Equipment)													
Electric (kWh)	699.0	622.5	638.9	447.8	311.3	311.3	54.6	136.5	188.4	360.4	606.2	562.5	4,939.3
Peak (kW)	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Eq5307 - Boiler cntl panel & inter (Misc Accessory Equipment)													
Electric (kWh)	128.0	114.0	117.0	82.0	57.0	57.0	10.0	25.0	34.5	66.0	111.0	103.0	904.5
Peak (kW)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

EQUIPMENT ENERGY CONSUMPTION
By ae

Alternative: 1 Palestra Building

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Consumption -------								
Hpl 1: BOILERS													
Boiler 4 (Heating Equipment)													
Gas (kWh)	257,550.5	235,986.4	280,975.7	218,452.8	111,945.3	98,637.2	19,512.2	5,717.9	36,875.7	100,372.3	232,103.8	213,651.8	1,811,781.6
Peak (kW)	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6
Eq5020 - Heating water circ pump (Misc Accessory Equipment)													
Electric (kWh)	233,025.0	206,700.0	209,625.0	159,900.0	111,150.0	111,150.0	19,500.0	7,800.0	41,925.0	112,125.0	216,450.0	200,850.0	1,630,200.0
Peak (kW)	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0
Eq5240 - Boiler forced draft fan (Misc Accessory Equipment)													
Electric (kWh)	652.6	578.8	587.0	447.8	311.3	311.3	54.6	21.8	117.4	314.0	606.2	562.5	4,565.2
Peak (kW)	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Eq5307 - Boiler cntl panel & inter (Misc Accessory Equipment)													
Electric (kWh)	119.5	106.0	107.5	82.0	57.0	57.0	10.0	4.0	21.5	57.5	111.0	103.0	836.0
Peak (kW)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

MONTHLY ENERGY CONSUMPTION

By ae

Alternative: 1 Palestra Building

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Energy Consumption -------												
Electric													
On-Pk Cons. (kWh)	2,005,564	1,819,345	2,105,694	1,692,834	1,633,466	1,621,389	1,280,122	1,502,611	1,353,867	1,659,670	1,911,922	1,807,670	20,394,152
On-Pk Demand (kW)	7,543	7,687	7,687	7,456	7,352	7,316	7,321	7,349	7,306	7,317	7,454	7,694	7,694
Gas													
On-Pk Cons. (kWh)	1,091,644	1,038,849	1,233,092	910,244	535,245	488,491	124,989	214,481	276,792	517,039	969,033	888,768	8,288,669
On-Pk Demand (kW)	3,902	3,902	3,902	3,902	3,902	3,902	3,902	3,902	3,902	3,902	3,902	3,902	3,902

Building Energy Consumption = 3,332 MJ/(m2-year)
Source Energy Consumption = 8,123 MJ/(m2-year)
Floor Area = 30,992 m2

ENERGY CONSUMPTION SUMMARY

By ae

	Elect Cons. (kWh)	Gas Cons. (kwh)	Percent of Total Energy	Total Source Energy* (kWh/yr)
Primary heating				
Primary heating	26,269.6	8,288,669.0	29.0 %	8,803,731.0
Primary cooling				
Cooling Compressor	38,123.2		0.1 %	114,381.1
Tower/Cond Fans	23,232.9		0.1 %	69,705.7
Condenser Pump	10,650.8		0.0 %	31,955.5
Other CLG Accessories	130.8		0.0 %	392.4
Cooling Subtotal....	72,137.7		0.3 %	216,434.7
Auxiliary				
Supply Fans	7,931,724.5		27.7 %	23,797,552.0
Circ Pumps	7,929,899.5		27.7 %	23,792,076.0
Base Utilities			0.0 %	0.0
Aux Subtotal....	15,861,624.0		55.3 %	47,589,628.0
Lighting				
Lighting	1,623,302.6		5.7 %	4,870,394.5
Receptacle				
Receptacles	2,810,820.3		9.8 %	8,433,304.0
Heating plant load				
Base Utilities			0.0 %	0.0
Cogeneration				
Cogeneration			0.0 %	0.0
Totals				
Totals**	20,394,154.0	8,288,669.0	100.0 %	69,913,488.0

* Note: Resource Utilization factors are included in the Total Source Energy value.
** Note: This report can display a maximum of 6 utilities. If additional utilities are used, they will be included in the total.

MONTHLY UTILITY COSTS

By ae

Alternative: 1

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Utility Costs -------								
Electric													
On-Pk Cons. ($)	165,872	150,480	174,149	140,023	135,116	134,118	105,910	124,300	112,006	137,282	158,132	149,515	1,686,906
Off-Pk Cons. ($)	101	101	101	101	101	101	101	101	101	101	101	101	1,207
Total ($):	165,973	150,581	174,249	140,124	135,217	134,219	106,011	124,401	112,106	137,383	158,233	149,616	1,688,113
Gas													
On-Pk Cons. ($)	3,466	3,299	3,916	2,890	1,700	1,551	397	681	879	1,642	3,077	2,822	26,320
Monthly Total ($):	169,440	153,880	178,165	143,014	136,917	135,770	106,408	125,082	112,985	139,025	161,310	152,438	1,714,433

ELECTRICAL PEAK CHECKSUMS

By ae

Alternative: 1 Palestra Building
Yearly Time of Peak: 14(Hr) 7(Month)

Equipment Description		Electrical Demand (kw)	Percent of Total (%)
Cooling Equipment			
Chiller 2		0.74	0.01
	Sub total	0.74	0.01
Heating Equipment			
Boiler 1		978.23	12.72
	Sub total	978.23	12.72
Fan Equipment			
SUMMATION OF FAN ELECTRICAL DEMAND		1,350.00	17.56
SUMMATION OF FAN ELECTRICAL DEMAND		1,350.00	17.56
SUMMATION OF FAN ELECTRICAL DEMAND		40.00	0.52
SUMMATION OF FAN ELECTRICAL DEMAND		55.00	0.72
SUMMATION OF FAN ELECTRICAL DEMAND		55.00	0.72
	Sub total	2,850.00	37.08
Miscellaneous			
Lights		329.39	4.28
Base Utilities		0.00	0.00
Misc Equipment		601.41	7.82
	Sub total	930.80	12.10
	Total	4,759.77	62

YEARLY CASH FLOW

By ae

Alternative: 1
Life Cycle Cost: 31,868,440.64

Year	Utility Cost ($)	Maint. Cost ($)	Interest Cost ($)	Principal Cost ($)	Property Taxes ($)	Insurance Cost ($)	Revenue Penalty ($)	Replace. Expenses ($)	Deprec. Tax ($)	Cash Flow Effect ($)	Present Value ($)
0	0	0	0	17,826,732	0	0	0	0	0	17,826,732	17,826,732
1	1,714,433	306,000	0	0	0	0	0	0	891,337	1,438,079	1,250,504
2	1,714,433	367,200	0	0	0	0	0	0	891,337	1,487,039	1,124,415
3	1,714,433	440,640	0	0	0	0	0	0	891,337	1,545,791	1,016,383
4	1,714,433	528,768	0	0	0	0	0	0	891,337	1,616,294	924,121
5	1,714,433	634,522	0	0	0	0	0	0	891,337	1,700,897	845,646
6	1,714,433	761,426	0	0	0	0	0	0	891,337	1,802,420	779,236
7	1,714,433	913,711	0	0	0	0	0	0	891,337	1,924,248	723,396
8	1,714,433	1,096,453	0	0	0	0	0	0	891,337	2,070,442	676,831
9	1,714,433	1,315,744	0	0	0	0	0	0	891,337	2,245,875	638,418
10	1,714,433	1,578,893	0	0	0	0	0	0	891,337	2,456,394	607,183
11	1,714,433	1,894,671	0	0	0	0	0	0	891,337	2,709,016	582,285
12	1,714,433	2,273,605	0	0	0	0	0	0	891,337	3,012,164	562,995
13	1,714,433	2,728,326	0	0	0	0	0	0	891,337	3,375,941	548,685
14	1,714,433	3,273,992	0	0	0	0	0	0	891,337	3,812,473	538,812
15	1,714,433	3,928,790	0	0	0	0	0	0	891,337	4,336,311	532,909
16	1,714,433	4,714,548	0	0	0	0	0	0	891,337	4,964,918	530,575
17	1,714,433	5,657,457	0	0	0	0	0	0	891,337	5,719,245	531,466
18	1,714,433	6,788,949	0	0	0	0	0	0	891,337	6,624,439	535,289
19	1,714,433	8,146,739	0	0	0	0	0	0	891,337	7,710,670	541,793
20	1,714,433	9,776,086	0	0	0	0	0	0	891,337	9,014,148	550,767

TRACE® 700 Economic Summary

By ae

Project Information

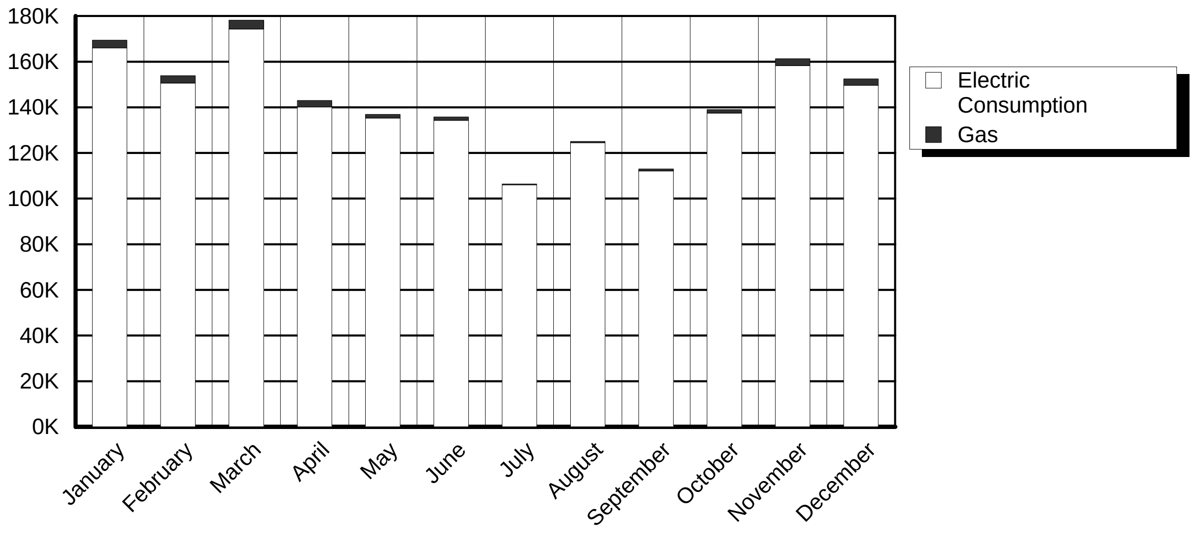
Weather file	Heathrow, England	Alternative 1 - - Palestra Building
Project Name		
Location	London, England	
Building Owner	Balckfriars Investment	
User		
Company	Penn State University	
Comments		

Economic Summary

Alternative Number	Installed Cost	First Year Util.Cost	Final Year Util. Cost	First Year Maint. Cost	Final Year Maint. Cost	Life Cycle Cost
1	17,826,732.00	1,714,433.42	1,714,433.42	306,000.00	9,776,086.14	31,868,440.64

Monthly Utility Costs per Utility

(1 alternative)



Equipment Energy Consumption by Alternative

	Elect Cons. (kWh)	Gas Cons. (kwh)	Percent of Total Energy	Total Source Energy* (kWh/yr)
Alternative: 1 - Palestra Building				
Primary heating	26,269.6	8,288,669.0	29.0%	8,803,731.0
Cooling Compressor	38,123.2		0.1%	114,381.1
Tower/Cond Fans	23,232.9		0.1%	69,705.7
Condenser Pump	10,650.8		0.0%	31,955.5
Other CLG Accessories	130.8		0.0%	392.4
Supply Fans	7,931,724.5		27.7%	23,797,552.0
Circ Pumps	7,929,899.5		27.7%	23,792,076.0
Lighting	1,623,302.6		5.7%	4,870,394.5
Totals	**20,394,154.0**	**8,288,669.0**	**100.0%**	**69,913,488.0**

* *Note: Resource Utilization factors are included in the Total Source Energy value.*

Natural Gas Engine Driven Chiller Plant Energy Simulation

EQUIPMENT ENERGY CONSUMPTION
By ae

Alternative: 1 Palestra Building

Equipment - Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
		-------	Monthly Consumption	-------										
Lights														
	Electric (kWh)	171,215.5	154,884.0	185,958.4	163,314.5	178,587.0	178,057.5	163,844.0	185,958.4	163,314.5	178,587.0	170,686.0	163,844.0	2,058,250.8
	Peak (kW)	640.1	640.1	640.1	640.1	640.1	640.1	640.1	640.1	640.1	640.1	640.1	640.1	640.1
MISC LD														
	Electric (kWh)	234,034.4	211,696.4	253,279.4	223,381.2	243,657.1	242,625.8	224,412.1	253,279.4	223,381.3	243,657.1	233,003.5	224,412.1	2,810,820.0
	Peak (kW)	816.2	816.2	816.2	816.2	816.2	816.2	816.2	816.2	816.2	816.2	816.2	816.2	816.2
AHU 1														
Eq4371 - Fan coil supply fan (Main Clg Fan)														
	Electric (kWh)	1,773.4	1,699.9	2,044.4	1,756.4	2,244.8	2,305.4	2,699.2	2,888.7	2,294.2	2,089.6	1,775.8	1,679.9	25,251.5
	Peak (kW)	9.5	9.5	9.5	9.5	9.5	10.0	10.0	10.0	9.5	9.5	9.5	9.5	10.0
AHU 2														
Eq4371 - Fan coil supply fan (Main Clg Fan)														
	Electric (kWh)	1,676.0	1,531.7	1,855.1	1,623.7	1,816.0	1,824.7	1,756.7	1,961.3	1,679.0	1,908.9	1,684.0	1,601.3	20,918.3
	Peak (kW)	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
AHU 3														
Eq4372 - Unit vent supply fan (Main Clg Fan)														
	Electric (kWh)	350.5	289.4	368.2	355.0	436.5	364.5	554.6	473.5	372.2	377.4	314.1	344.8	4,600.6
	Peak (kW)	4.9	5.1	4.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	5.1	5.0	5.1
AHU 4														
Eq4372 - Unit vent supply fan (Main Clg Fan)														
	Electric (kWh)	350.3	338.7	418.4	345.5	524.5	515.4	832.2	792.6	563.3	400.8	360.3	331.1	5,773.0
	Peak (kW)	5.5	5.5	5.5	5.3	5.4	4.7	5.5	5.0	4.7	4.9	5.5	5.5	5.5
AHU 7														

EQUIPMENT ENERGY CONSUMPTION
By ae

Alternative: 1 Palestra Building

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Consumption -------								
AHU 7													
Eq4371 - Fan coil supply fan (Main Clg Fan)													
Electric (kWh)	1,900.5	1,719.5	2,081.5	1,810.0	1,991.0	1,991.0	1,810.0	2,081.5	1,810.0	1,991.0	1,900.5	1,810.0	22,896.5
Peak (kW)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Cpl 1: IC Engine Chiller Plant													
IC Chiller 1 (Cooling Equipment)													
Gas (kWh)	622.7	467.9	621.4	1,056.5	5,550.6	8,379.2	32,928.5	16,273.2	9,352.1	4,416.9	710.3	662.4	81,041.5
Peak (kW)	80.3	80.2	80.1	94.5	94.5	94.5	393.7	193.9	141.8	94.5	85.6	94.5	393.7
Eq5100 - Cooling tower													
Electric (kWh)	2,260.9	2,026.9	2,450.6	2,311.0	4,401.3	4,531.9	6,880.6	6,962.3	4,951.1	4,005.2	2,342.0	2,252.0	45,375.5
Peak (kW)	13.6	13.9	14.2	16.8	21.5	21.5	21.5	21.5	21.5	18.1	14.1	15.1	21.5
Eq5100 - Cooling tower													
Make Up Water (kL)	124.3	112.1	143.0	145.9	392.4	364.8	1,294.6	708.0	456.7	216.4	128.3	119.0	4,205.4
Peak (kL/Hr)	3.6	3.8	4.1	4.8	5.5	6.0	11.3	8.0	6.5	4.8	3.7	3.7	11.3
Eq5001 - Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	14.6	10.9	14.6	29.2	262.7	361.2	474.3	461.5	328.3	268.2	21.9	16.4	2,263.7
Peak (kW)	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Eq5010 - Cnst vol cnd water pump (Misc Accessory Equipment)													
Electric (kWh)	25.1	18.8	25.1	50.1	451.1	620.2	814.4	792.5	563.8	460.5	37.6	28.2	3,887.3
Peak (kW)	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Eq5300 - Cntl panel & interlocks (Misc Accessory Equipment)													
Electric (kWh)	8.0	6.0	8.0	16.0	144.0	198.0	260.0	253.0	180.0	147.0	12.0	9.0	1,241.0
Peak (kW)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
EDC Heater (Misc Accessory Equipment)													
Electric (kWh)	110.4	99.9	110.4	105.6	90.0	78.3	72.6	73.7	81.0	89.6	106.2	110.3	1,127.9
Peak (kW)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
IC CHiller 2 (Cooling Equipment)													
Gas (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	7,500.0	0.0	0.0	0.0	0.0	0.0	7,500.0
Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	393.7	193.9	0.0	0.0	0.0	0.0	393.7

EQUIPMENT ENERGY CONSUMPTION

By ae

Alternative: 1   Palestra Building

------- Monthly Consumption -------

Equipment - Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Cpl 1: IC Engine Chiller Plant														
Eq5100 - Cooling tower														
	Electric (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	965.3	0.0	0.0	0.0	0.0	0.0	965.3
	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	21.5	21.5	0.0	0.0	0.0	0.0	21.5
Eq5100 - Cooling tower														
	Make Up Water (kL)	0.0	0.0	0.0	0.0	0.0	0.0	79.3	0.0	0.0	0.0	0.0	0.0	79.3
	Peak (kL/Hr)	0.0	0.0	0.0	0.0	0.0	0.0	3.3	2.0	0.0	0.0	0.0	0.0	3.3
Eq5001 - Cnst vol chill water pump (Misc Accessory Equipment)														
	Electric (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	82.1	0.0	0.0	0.0	0.0	0.0	82.1
	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	1.8	1.8	0.0	0.0	0.0	0.0	1.8
Eq5010 - Cnst vol cnd water pump (Misc Accessory Equipment)														
	Electric (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	141.0	0.0	0.0	0.0	0.0	0.0	141.0
	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	3.1	3.1	0.0	0.0	0.0	0.0	3.1
Eq5300 - Cntl panel & interlocks (Misc Accessory Equipment)														
	Electric (kWh)	0.0	0.0	0.0	0.0	0.0	0.0	45.0	0.0	0.0	0.0	0.0	0.0	45.0
	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	1.0
EDC Heater (Misc Accessory Equipment)														
	Electric (kWh)	111.6	100.8	111.6	108.0	111.6	108.0	104.9	111.6	108.0	111.6	108.0	111.6	1,307.3
	Peak (kW)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
IC Chiller 3 (Cooling Equipment)														
Gas	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	393.7	0.0	0.0	0.0	0.0	0.0	393.7
Eq5100 - Cooling tower														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	21.5	0.0	0.0	0.0	0.0	0.0	21.5
Eq5100 - Cooling tower														
Make Up Water	Peak (kL/Hr)	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	3.3
Eq5001 - Cnst vol chill water pump (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	1.8
Eq5010 - Cnst vol cnd water pump (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0	3.1
Eq5300 - Cntl panel & interlocks (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0

EQUIPMENT ENERGY CONSUMPTION

By ae

Alternative: 1 Palestra Building

Equipment - Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
		-------				Monthly Consumption			-------					
Cpl 1: IC Engine Chiller Plant														
EDC Heater (Misc Accessory Equipment)														
	Electric (kWh)	111.6	100.8	111.6	108.0	111.6	108.0	111.6	111.6	108.0	111.6	108.0	111.6	1,314.0
	Peak (kW)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
IC CHiller 4 (Cooling Equipment)														
Gas	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	393.7	0.0	0.0	0.0	0.0	0.0	393.7
Eq5100 - Cooling tower														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	21.5	0.0	0.0	0.0	0.0	0.0	21.5
Eq5100 - Cooling tower														
Make Up Water	Peak (kL/Hr)	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	3.3
Eq5001 - Cnst vol chill water pump (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	1.8
Eq5010 - Cnst vol cnd water pump (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0	3.1
Eq5300 - Cntl panel & interlocks (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
EDC Heater (Misc Accessory Equipment)														
	Electric (kWh)	111.6	100.8	111.6	108.0	111.6	108.0	111.6	111.6	108.0	111.6	108.0	111.6	1,314.0
	Peak (kW)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
IC Chiller 5 (Cooling Equipment)														
Gas	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	393.7	0.0	0.0	0.0	0.0	0.0	393.7
Eq5100 - Cooling tower														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	21.5	0.0	0.0	0.0	0.0	0.0	21.5
Eq5100 - Cooling tower														
Make Up Water	Peak (kL/Hr)	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	3.3
Eq5001 - Cnst vol chill water pump (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	1.8
Eq5010 - Cnst vol cnd water pump (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0	3.1
Eq5300 - Cntl panel & interlocks (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0

EQUIPMENT ENERGY CONSUMPTION
By ae

Alternative: 1 Palestra Building

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Consumption -------								
Cpl 1: IC Engine Chiller Plant													
EDC Heater (Misc Accessory Equipment)													
Electric (kWh)	111.6	100.8	111.6	108.0	111.6	108.0	111.6	111.6	108.0	111.6	108.0	111.6	1,314.0
Peak (kW)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Hpl 1: BOILERS													
Boiler 1 (Heating Equipment)													
Gas (kWh)	287,220.4	279,779.7	337,934.0	244,647.7	171,879.6	159,275.1	51,019.5	101,100.0	100,938.4	163,548.8	256,205.4	232,689.0	2,386,237.8
Peak (kW)	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6
Eq5020 - Heating water circ pump (Misc Accessory Equipment)													
Electric (kWh)	294,450.0	265,200.0	321,750.0	253,500.0	235,950.0	210,600.0	63,375.0	142,350.0	158,925.0	193,050.0	286,650.0	273,000.0	2,698,800.0
Peak (kW)	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0
Eq5240 - Boiler forced draft fan (Misc Accessory Equipment)													
Electric (kWh)	824.6	742.7	901.0	709.9	660.8	589.8	177.5	398.6	445.1	540.6	802.7	764.5	7,557.8
Peak (kW)	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Eq5307 - Boiler cntl panel & inter (Misc Accessory Equipment)													
Electric (kWh)	151.0	136.0	165.0	130.0	121.0	108.0	32.5	73.0	81.5	99.0	147.0	140.0	1,384.0
Peak (kW)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Boiler 2 (Heating Equipment)													
Gas (kWh)	264,735.0	255,915.5	304,971.0	228,864.8	131,597.7	114,175.3	33,527.9	74,469.3	76,375.6	131,404.7	235,156.8	220,487.8	2,071,681.4
Peak (kW)	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6
Eq5020 - Heating water circ pump (Misc Accessory Equipment)													
Electric (kWh)	233,025.0	225,225.0	273,000.0	175,500.0	132,600.0	115,050.0	43,875.0	93,600.0	86,775.0	128,700.0	179,400.0	164,775.0	1,851,525.0
Peak (kW)	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0
Eq5240 - Boiler forced draft fan (Misc Accessory Equipment)													
Electric (kWh)	652.6	630.7	764.5	491.5	371.3	322.2	122.9	262.1	243.0	360.4	502.4	461.4	5,185.0
Peak (kW)	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Eq5307 - Boiler cntl panel & inter (Misc Accessory Equipment)													
Electric (kWh)	119.5	115.5	140.0	90.0	68.0	59.0	22.5	48.0	44.5	66.0	92.0	84.5	949.5
Peak (kW)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

EQUIPMENT ENERGY CONSUMPTION

By ae

Alternative: 1 Palestra Building

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Consumption -------								
Hpl 1: BOILERS													
Boiler 3 (Heating Equipment)													
Gas (kWh)	257,561.1	242,992.9	280,975.7	218,536.6	115,121.9	111,219.5	19,512.2	34,470.0	60,869.8	112,195.1	227,055.0	218,329.6	1,898,839.4
Peak (kW)	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6
Eq5020 - Heating water circ pump (Misc Accessory Equipment)													
Electric (kWh)	216,450.0	209,625.0	235,950.0	175,500.0	115,050.0	111,150.0	19,500.0	48,750.0	67,275.0	112,125.0	175,500.0	164,775.0	1,651,650.0
Peak (kW)	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0
Eq5240 - Boiler forced draft fan (Misc Accessory Equipment)													
Electric (kWh)	606.2	587.0	660.8	491.5	322.2	311.3	54.6	136.5	188.4	314.0	491.5	461.4	4,625.3
Peak (kW)	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Eq5307 - Boiler cntl panel & inter (Misc Accessory Equipment)													
Electric (kWh)	111.0	107.5	121.0	90.0	59.0	57.0	10.0	25.0	34.5	57.5	90.0	84.5	847.0
Peak (kW)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Boiler 4 (Heating Equipment)													
Gas (kWh)	247,156.2	231,219.4	280,975.7	208,181.2	113,339.2	97,531.8	19,512.2	6,035.5	35,733.9	90,007.1	216,585.4	191,049.7	1,737,327.1
Peak (kW)	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6	975.6
Eq5020 - Heating water circ pump (Misc Accessory Equipment)													
Electric (kWh)	216,450.0	194,025.0	235,950.0	175,500.0	115,050.0	111,150.0	19,500.0	7,800.0	41,925.0	112,125.0	175,500.0	161,850.0	1,566,825.0
Peak (kW)	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0
Eq5240 - Boiler forced draft fan (Misc Accessory Equipment)													
Electric (kWh)	606.2	543.4	660.8	491.5	322.2	311.3	54.6	21.8	117.4	314.0	491.5	453.3	4,387.8
Peak (kW)	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Eq5307 - Boiler cntl panel & inter (Misc Accessory Equipment)													
Electric (kWh)	111.0	99.5	121.0	90.0	59.0	57.0	10.0	4.0	21.5	57.5	90.0	83.0	803.5
Peak (kW)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

MONTHLY ENERGY CONSUMPTION

By ae

Alternative: 1   Palestra Building

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Energy Consumption -------												
Electric													
On-Pk Cons. (kWh)	1,377,723	1,271,762	1,519,245	1,178,114	1,035,685	983,671	552,818	749,894	756,026	982,237	1,232,433	1,163,818	12,803,427
On-Pk Demand (kW)	5,395	5,396	5,397	5,397	5,404	5,407	5,222	5,352	5,346	5,409	5,396	5,399	5,409
Gas													
On-Pk Cons. (kWh)	1,057,295	1,010,376	1,205,477	901,287	537,489	490,581	164,000	232,348	283,270	501,573	935,713	863,219	8,182,627
On-Pk Demand (kW)	3,983	3,983	3,982	3,997	3,997	3,997	3,997	3,997	3,997	3,997	3,988	3,997	3,997
Water													
Cons. (kL)	124	112	143	146	392	365	1,374	708	457	216	128	119	4,285

Building Energy Consumption = 2,438 MJ/(m2-year)
Source Energy Consumption = 5,464 MJ/(m2-year)
Floor Area = 30,992 m2

ENERGY CONSUMPTION SUMMARY

By ae

	Elect Cons. (kWh)	Gas Cons. (kwh)	Water Cons. (kL)	Percent of Total Energy	Total Source Energy* (kWh/yr)
Primary heating					
Primary heating	25,739.8	8,094,085.5		38.7 %	8,597,317.0
Primary cooling					
Cooling Compressor		88,541.5		0.4 %	93,201.6
Tower/Cond Fans	46,340.8		4,284.7	0.2 %	139,036.2
Condenser Pump	4,028.2			0.0 %	12,085.9
Other CLG Accessories	7,663.1			0.0 %	22,991.6
Cooling Subtotal....	58,032.1	88,541.5	4,284.7	0.7 %	267,315.3
Auxiliary					
Supply Fans	79,439.9			0.4 %	238,343.6
Circ Pumps	7,771,146.0			37.0 %	23,315,768.0
Base Utilities				0.0 %	0.0
Aux Subtotal....	7,850,586.0			37.4 %	23,554,112.0
Lighting					
Lighting	2,058,250.8			9.8 %	6,175,369.5
Receptacle					
Receptacles	2,810,820.3			13.4 %	8,433,304.0
Heating plant load					
Base Utilities				0.0 %	0.0
Cogeneration					
Cogeneration				0.0 %	0.0
Totals					
Totals**	12,803,429.0	8,182,627.0	4,284.7	100.0 %	47,027,416.0

* Note: Resource Utilization factors are included in the Total Source Energy value.
** Note: This report can display a maximum of 6 utilities. If additional utilities are used, they will be included in the total.

MONTHLY UTILITY COSTS

By ae

Alternative: 1

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Utility Costs -------								
Electric													
On-Pk Cons. ($)	113,978	105,219	125,675	97,479	85,706	81,407	45,794	62,084	62,591	81,288	101,969	96,297	1,059,487
Off-Pk Cons. ($)	101	101	101	101	101	101	101	101	101	101	101	101	1,207
Total ($):	114,078	105,320	125,776	97,579	85,807	81,507	45,895	62,184	62,691	81,389	102,069	96,398	1,060,694
Gas													
On-Pk Cons. ($)	3,357	3,208	3,828	2,862	1,707	1,558	521	738	900	1,593	2,971	2,741	25,984
Monthly Total ($):	117,436	108,528	129,604	100,441	87,514	83,065	46,416	62,922	63,591	82,982	105,040	99,139	1,086,678

ELECTRICAL PEAK CHECKSUMS

By ae

Alternative: 1 Palestra Building
Yearly Time of Peak: 17(Hr) 7(Month)

Equipment Description		Electrical Demand (kw)	Percent of Total (%)
Cooling Equipment			
IC Chiller 1		15.36	0.28
IC CHiller 2		0.15	0.00
IC Chiller 3		0.15	0.00
IC CHiller 4		0.15	0.00
IC Chiller 5		0.15	0.00
	Sub total	15.96	0.28
Heating Equipment			
Boiler 1		978.23	18.13
	Sub total	978.23	18.13
Fan Equipment			
SUMMATION OF FAN ELECTRICAL DEMAND		2.04	0.04
SUMMATION OF FAN ELECTRICAL DEMAND		0.47	0.01
SUMMATION OF FAN ELECTRICAL DEMAND		10.00	0.19
SUMMATION OF FAN ELECTRICAL DEMAND		2.45	0.05
SUMMATION OF FAN ELECTRICAL DEMAND		0.85	0.02
	Sub total	15.81	0.31
Miscellaneous			
Lights		640.05	11.86
Base Utilities		0.00	0.00
Misc Equipment		816.20	15.12
	Sub total	1,456.25	26.98
	Total	2,466.25	46

YEARLY CASH FLOW

By ae

Alternative: 1
Life Cycle Cost: 28,724,974.84

Year	Utility Cost ($)	Maint. Cost ($)	Interest Cost ($)	Principal Cost ($)	Property Taxes ($)	Insurance Cost ($)	Revenue Penalty ($)	Replace. Expenses ($)	Deprec. Tax ($)	Cash Flow Effect ($)	Present Value ($)
0	0	0	0	17,826,732	0	0	0	0	0	17,826,732	17,826,732
1	1,086,678	306,000	0	0	0	0	0	0	891,337	935,875	813,804
2	1,086,678	367,200	0	0	0	0	0	0	891,337	984,835	744,677
3	1,086,678	440,640	0	0	0	0	0	0	891,337	1,043,587	686,175
4	1,086,678	528,768	0	0	0	0	0	0	891,337	1,114,089	636,984
5	1,086,678	634,522	0	0	0	0	0	0	891,337	1,198,692	595,962
6	1,086,678	761,426	0	0	0	0	0	0	891,337	1,300,215	562,119
7	1,086,678	913,711	0	0	0	0	0	0	891,337	1,422,044	534,599
8	1,086,678	1,096,453	0	0	0	0	0	0	891,337	1,568,237	512,660
9	1,086,678	1,315,744	0	0	0	0	0	0	891,337	1,743,670	495,660
10	1,086,678	1,578,893	0	0	0	0	0	0	891,337	1,954,189	483,046
11	1,086,678	1,894,671	0	0	0	0	0	0	891,337	2,206,812	474,339
12	1,086,678	2,273,605	0	0	0	0	0	0	891,337	2,509,959	469,129
13	1,086,678	2,728,326	0	0	0	0	0	0	891,337	2,873,736	467,062
14	1,086,678	3,273,992	0	0	0	0	0	0	891,337	3,310,268	467,836
15	1,086,678	3,928,790	0	0	0	0	0	0	891,337	3,834,107	471,191
16	1,086,678	4,714,548	0	0	0	0	0	0	891,337	4,462,713	476,907
17	1,086,678	5,657,457	0	0	0	0	0	0	891,337	5,217,041	484,798
18	1,086,678	6,788,949	0	0	0	0	0	0	891,337	6,122,234	494,708
19	1,086,678	8,146,739	0	0	0	0	0	0	891,337	7,208,466	506,505
20	1,086,678	9,776,086	0	0	0	0	0	0	891,337	8,511,944	520,082

TRACE® 700 Economic Summary

By ae

Project Information

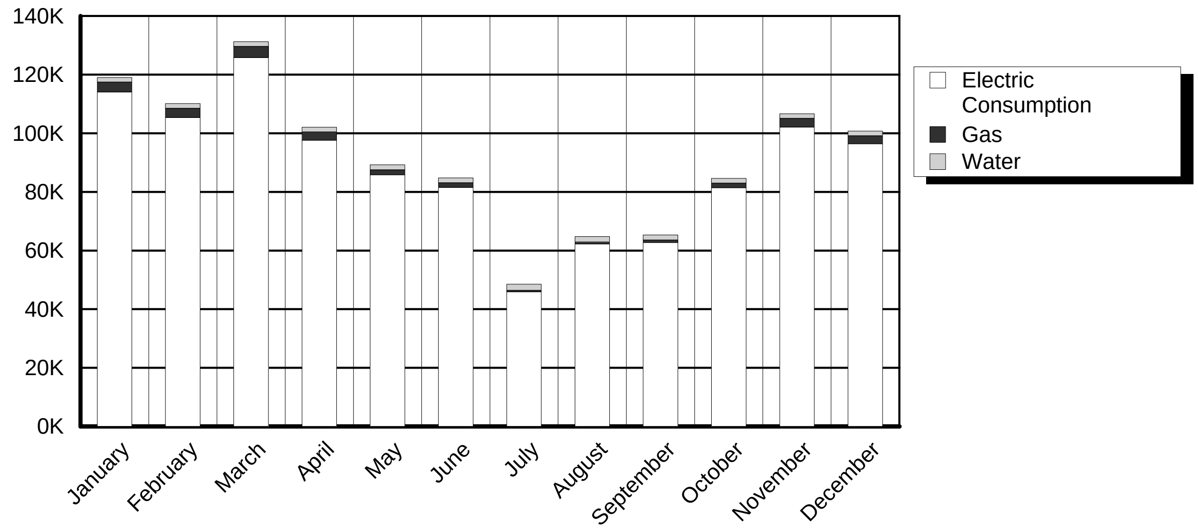
Weather file	Heathrow, England	Alternative 1 - - Palestra Building
Project Name		
Location	London, England	
Building Owner	Balckfriars Investment	
User		
Company	Penn State University	
Comments		

Economic Summary

Alternative Number	Installed Cost	First Year Util.Cost	Final Year Util. Cost	First Year Maint. Cost	Final Year Maint. Cost	Life Cycle Cost
1	18,112,724.00	1,107,063.98	1,107,063.98	306,000.00	9,776,086.14	29,095,149.96

Monthly Utility Costs per Utility

(1 alternative)



Equipment Energy Consumption by Alternative

	Elect Cons. (kWh)	Gas Cons. (kwh)	Water Cons. (liters)	Percent of Total Energy	Total Source Energy* (kWh/yr)
Alternative: 1 - Palestra Building					
Primary heating	25,739.8	8,094,085.5		38.7%	8,597,317.0
Cooling Compressor		88,541.5		0.4%	93,201.6
Tower/Cond Fans	46,340.8		4,284.7	0.2%	139,036.2
Condenser Pump	4,028.2			0.0%	12,085.9
Other CLG Accessories	7,663.1			0.0%	22,991.6
Supply Fans	79,439.9			0.4%	238,343.6
Circ Pumps	7,771,146.0			37.0%	23,315,768.0
Lighting	2,058,250.8			9.8%	6,175,369.5
Totals	**12,803,429.0**	**8,182,627.0**	**4,284.7**	**100.0%**	**47,027,416.0**

* *Note: Resource Utilization factors are included in the Total Source Energy value.*

Dedicated Outdoor Air System Energy Simulation

EQUIPMENT ENERGY CONSUMPTION
By ae

Alternative: 1 Palestra Building

------- Monthly Consumption -------

Equipment - Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Lights														
	Electric (kWh)	26,869.5	24,305.9	29,140.7	25,636.5	28,005.2	27,907.7	25,733.9	29,140.7	25,636.5	28,005.1	26,772.1	25,733.9	322,887.8
	Peak (kW)	97.7	97.7	97.7	97.7	97.7	97.7	97.7	97.7	97.7	97.7	97.7	97.7	97.7
MISC LD														
	Electric (kWh)	42,556.8	38,494.9	46,056.4	40,619.6	44,306.7	44,119.2	40,807.1	46,056.4	40,619.7	44,306.7	42,369.4	40,807.1	511,119.9
	Peak (kW)	148.4	148.4	148.4	148.4	148.4	148.4	148.4	148.4	148.4	148.4	148.4	148.4	148.4

AHU 3 DOAS

Eq4372 - Unit vent supply fan (Main Clg Fan)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	Electric (kWh)	9,933.0	9,244.8	10,208.7	6,768.3	3,557.9	3,255.1	5,253.7	3,083.8	3,823.7	7,507.6	10,277.8	9,804.8	82,719.2
	Peak (kW)	55.0	55.0	55.0	55.0	55.0	55.0	54.9	51.4	55.0	55.0	55.0	55.0	55.0

AHU 4 DOAS

Eq4372 - Unit vent supply fan (Main Clg Fan)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	Electric (kWh)	9,933.0	9,358.5	10,454.2	6,422.3	3,255.6	3,075.7	5,880.5	3,224.1	3,071.8	7,064.3	10,282.4	9,537.8	81,560.2
	Peak (kW)	55.0	55.0	55.0	55.0	55.0	53.4	55.0	43.6	55.0	55.0	55.0	55.0	55.0

AHU DOAS 1

Eq4371 - Fan coil supply fan (Main Clg Fan)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	Electric (kWh)	285,833.6	258,752.1	316,639.5	288,376.0	353,275.5	366,008.5	354,184.3	403,746.6	333,903.9	332,078.9	289,910.3	276,110.4	3,858,819.8
	Peak (kW)	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0

AHU DOAS 2

Eq4371 - Fan coil supply fan (Main Clg Fan)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	Electric (kWh)	285,021.1	257,552.2	311,965.2	281,604.2	327,899.3	332,123.8	349,410.6	385,116.4	313,078.7	316,818.9	280,214.3	272,554.4	3,713,359.0
	Peak (kW)	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0	1,425.0

AHU DOAS 7

EQUIPMENT ENERGY CONSUMPTION
By ae

Alternative: 1 Palestra Building

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Consumption -------								
AHU DOAS 7													
Eq4371 - Fan coil supply fan (Main Clg Fan)													
Electric (kWh)	76,020.0	68,780.0	83,260.0	72,400.0	79,640.0	79,640.0	72,400.0	83,260.0	72,400.0	79,640.0	76,020.0	72,400.0	915,860.0
Peak (kW)	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0	400.0
Cpl 1: CHILLERS													
Chiller 2 (Cooling Equipment)													
Electric (kWh)	74,462.7	67,254.1	74,462.5	72,071.4	74,708.3	72,858.9	75,280.6	77,756.5	73,316.3	74,553.4	72,061.5	74,462.0	883,248.2
Peak (kW)	104.1	104.1	104.1	104.6	121.0	128.2	133.3	133.2	137.9	122.0	104.2	104.4	137.9
Eq5221 - Condenser fan													
Electric (kWh)	9,929.7	9,017.1	10,065.8	9,674.0	10,207.6	9,876.1	9,503.0	10,756.8	10,166.6	10,119.5	9,705.8	9,963.0	118,984.9
Peak (kW)	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2
Eq5001 - Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	682.2	616.2	682.2	660.2	682.2	660.2	682.2	682.2	660.2	682.2	660.2	682.2	8,032.8
Peak (kW)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Eq5011 - Cnst vol cnd water pump (Misc Accessory Equipment)													
Electric (kWh)	6,002.9	5,422.0	6,002.9	5,809.3	6,002.9	5,809.3	6,002.9	6,002.9	5,809.3	6,002.9	5,809.3	6,002.9	70,679.6
Peak (kW)	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
Eq5302 - Cntl panel & interlocks (Misc Accessory Equipment)													
Electric (kWh)	74.4	67.2	74.4	72.0	74.4	72.0	74.4	74.4	72.0	74.4	72.0	74.4	876.0
Peak (kW)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Chiller 3 (Cooling Equipment)													
Electric (kWh)	416.4	312.3	416.3	418.3	419.5	420.2	18,143.0	1,959.1	315.2	523.8	416.8	313.3	24,074.2
Peak (kW)	104.1	104.1	104.1	104.6	104.9	105.1	131.8	118.2	105.1	104.8	104.2	104.4	131.8
Eq5221 - Condenser fan													
Electric (kWh)	51.8	38.8	51.7	52.0	52.2	52.3	2,141.0	245.5	39.2	65.1	51.8	38.9	2,880.2
Peak (kW)	12.9	12.9	12.9	13.0	13.0	13.1	14.8	13.6	13.1	13.0	13.0	13.0	14.8
Eq5001 - Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	3.7	2.8	3.7	3.7	3.7	3.7	183.4	21.1	2.8	4.6	3.7	2.8	239.3
Peak (kW)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

EQUIPMENT ENERGY CONSUMPTION

By ae

Alternative: 1 Palestra Building

Equipment - Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
		------- Monthly Consumption -------												
Cpl 1: CHILLERS														
Eq5012 - Cnst vol cnd water pump (Misc Accessory Equipment)														
	Electric (kWh)	38.8	29.1	38.8	38.8	38.8	38.8	1,937.8	222.9	29.1	48.4	38.8	29.1	2,528.8
	Peak (kW)	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
Eq5302 - Cntl panel & interlocks (Misc Accessory Equipment)														
	Electric (kWh)	0.4	0.3	0.4	0.4	0.4	0.4	20.0	2.3	0.3	0.5	0.4	0.3	26.1
	Peak (kW)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Chiller 4 (Cooling Equipment)														
	Electric (kWh)	416.2	312.2	416.1	418.1	419.2	420.0	2,480.4	421.5	315.0	523.5	416.6	313.1	6,871.8
	Peak (kW)	104.1	104.1	104.0	104.5	104.8	105.0	131.7	105.4	105.0	104.7	104.2	104.4	131.7
Eq5221 - Condenser fan														
	Electric (kWh)	51.7	38.8	51.7	52.0	52.1	52.2	290.4	52.4	39.2	65.1	51.8	38.9	836.5
	Peak (kW)	12.9	12.9	12.9	13.0	13.0	13.1	14.5	13.1	13.1	13.0	13.0	13.0	14.5
Eq5001 - Cnst vol chill water pump (Misc Accessory Equipment)														
	Electric (kWh)	3.7	2.8	3.7	3.7	3.7	3.7	22.9	3.7	2.8	4.6	3.7	2.8	61.4
	Peak (kW)	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Eq5011 - Cnst vol cnd water pump (Misc Accessory Equipment)														
	Electric (kWh)	32.3	24.2	32.3	32.3	32.3	32.3	201.7	32.3	24.2	40.3	32.3	24.2	540.6
	Peak (kW)	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
Eq5302 - Cntl panel & interlocks (Misc Accessory Equipment)														
	Electric (kWh)	0.4	0.3	0.4	0.4	0.4	0.4	2.5	0.4	0.3	0.5	0.4	0.3	6.7
	Peak (kW)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Chiller 5 (Cooling Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	113.9	0.0	0.0	0.0	0.0	0.0	113.9
Eq5221 - Condenser fan														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	12.4	0.0	0.0	0.0	0.0	0.0	12.4
Eq5001 - Cnst vol chill water pump (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.9
Eq5011 - Cnst vol cnd water pump (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	8.1	0.0	0.0	0.0	0.0	0.0	8.1

EQUIPMENT ENERGY CONSUMPTION

By ae

Alternative: 1 Palestra Building

Equipment - Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
		------- Monthly Consumption -------												
Cpl 1: CHILLERS														
Eq5302 - Cntl panel & interlocks (Misc Accessory Equipment)														
Electric	Peak (kW)	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Hpl 1: BOILERS														
Boiler 1 (Heating Equipment)														
	Gas (kWh)	150,923.0	139,198.3	163,219.6	93,904.9	39,733.7	38,581.3	10,992.3	19,381.0	26,485.3	78,093.5	126,214.7	130,800.2	1,017,527.9
	Peak (kW)	975.6	975.6	975.6	975.6	938.9	963.1	340.0	491.4	912.1	969.4	975.6	975.6	975.6
Eq5020 - Heating water circ pump (Misc Accessory Equipment)														
	Electric (kWh)	307,125.0	280,800.0	358,800.0	202,800.0	187,200.0	208,650.0	53,625.0	97,500.0	109,200.0	245,700.0	307,125.0	275,925.0	2,634,450.0
	Peak (kW)	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0	975.0
Eq5240 - Boiler forced draft fan (Misc Accessory Equipment)														
	Electric (kWh)	860.1	786.4	1,004.8	567.9	524.2	584.3	150.2	273.0	305.8	688.1	860.1	772.7	7,377.5
	Peak (kW)	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Eq5307 - Boiler cntl panel & inter (Misc Accessory Equipment)														
	Electric (kWh)	157.5	144.0	184.0	104.0	96.0	107.0	27.5	50.0	56.0	126.0	157.5	141.5	1,351.0
	Peak (kW)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Boiler 2 (Heating Equipment)														
	Gas (kWh)	34,884.7	33,547.3	36,369.7	7,086.8	0.0	0.0	0.0	0.0	0.0	0.0	32,597.3	24,106.5	168,592.4
	Peak (kW)	975.6	975.6	975.6	356.0	0.0	0.0	0.0	0.0	0.0	0.0	975.6	975.6	975.6
Eq5020 - Heating water circ pump (Misc Accessory Equipment)														
	Electric (kWh)	48,750.0	42,900.0	52,650.0	23,400.0	0.0	0.0	0.0	0.0	0.0	0.0	48,750.0	28,275.0	244,725.0
	Peak (kW)	975.0	975.0	975.0	975.0	0.0	0.0	0.0	0.0	0.0	0.0	975.0	975.0	975.0
Eq5240 - Boiler forced draft fan (Misc Accessory Equipment)														
	Electric (kWh)	136.5	120.1	147.4	65.5	0.0	0.0	0.0	0.0	0.0	0.0	136.5	79.2	685.3
	Peak (kW)	2.7	2.7	2.7	2.7	0.0	0.0	0.0	0.0	0.0	0.0	2.7	2.7	2.7
Eq5307 - Boiler cntl panel & inter (Misc Accessory Equipment)														
	Electric (kWh)	25.0	22.0	27.0	12.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	14.5	125.5
	Peak (kW)	0.5	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5

EQUIPMENT ENERGY CONSUMPTION
By ae

Alternative: 1 Palestra Building

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Hpl 1: BOILERS													
Boiler 3 (Heating Equipment)													
Gas (kWh)	14,936.6	14,530.4	13,203.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4,037.2	4,234.1	50,941.6
Peak (kW)	975.6	975.6	502.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	975.6	586.3	975.6
Eq5020 - Heating water circ pump (Misc Accessory Equipment)													
Electric (kWh)	24,375.0	21,450.0	26,325.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7,800.0	22,425.0	102,375.0
Peak (kW)	975.0	975.0	975.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	975.0	975.0	975.0
Eq5240 - Boiler forced draft fan (Misc Accessory Equipment)													
Electric (kWh)	68.3	60.1	73.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.8	62.8	286.7
Peak (kW)	2.7	2.7	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	2.7	2.7
Eq5307 - Boiler cntl panel & inter (Misc Accessory Equipment)													
Electric (kWh)	12.5	11.0	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	11.5	52.5
Peak (kW)	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5
Boiler 4 (Heating Equipment)													
Gas (kWh)	3,902.4	219.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	950.5	0.0	5,072.2
Peak (kW)	975.6	73.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	237.6	0.0	975.6
Eq5020 - Heating water circ pump (Misc Accessory Equipment)													
Electric (kWh)	3,900.0	2,925.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,900.0	0.0	10,725.0
Peak (kW)	975.0	975.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	975.0	0.0	975.0
Eq5240 - Boiler forced draft fan (Misc Accessory Equipment)													
Electric (kWh)	10.9	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.9	0.0	30.0
Peak (kW)	2.7	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0	2.7
Eq5307 - Boiler cntl panel & inter (Misc Accessory Equipment)													
Electric (kWh)	2.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	5.5
Peak (kW)	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5

MONTHLY ENERGY CONSUMPTION

By ae

Alternative: 1 Palestra Building

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Energy Consumption -------												
Electric													
On-Pk Cons. (kWh)	1,213,757	1,098,855	1,339,253	1,038,082	1,120,458	1,155,772	1,024,439	1,149,685	992,888	1,154,644	1,193,964	1,126,604	13,608,401
On-Pk Demand (kW)	7,331	6,632	5,594	4,463	4,046	4,046	3,697	4,022	4,046	4,046	6,839	5,658	7,331
Gas													
On-Pk Cons. (kWh)	204,647	187,495	212,792	100,992	39,734	38,581	10,992	19,381	26,485	78,093	163,800	159,141	1,242,134
On-Pk Demand (kW)	3,902	3,000	2,454	1,332	939	963	340	491	912	969	3,164	2,537	3,902

Building Energy Consumption = 4,792 MJ/(m2-year)
Source Energy Consumption = 13,597 MJ/(m2-year)
Floor Area = 11,158 m2

ENERGY CONSUMPTION SUMMARY

By ae

	Elect Cons. (kWh)	Gas Cons. (kwh)	Percent of Total Energy	Total Source Energy* (kWh/yr)
Primary heating				
Primary heating	9,914.1	1,242,134.0	8.4 %	1,337,254.8
Primary cooling				
Cooling Compressor	914,194.2		6.2 %	2,742,856.8
Tower/Cond Fans	122,701.5		0.8 %	368,141.3
Condenser Pump	73,749.0		0.5 %	221,269.0
Other CLG Accessories	908.8		0.0 %	2,726.7
Cooling Subtotal....	1,111,553.4		7.5 %	3,334,993.5
Auxiliary				
Supply Fans	8,652,317.0		58.3 %	25,959,544.0
Circ Pumps	3,000,608.5		20.2 %	9,002,725.0
Base Utilities			0.0 %	0.0
Aux Subtotal....	11,652,926.0		78.5 %	34,962,272.0
Lighting				
Lighting	322,887.8		2.2 %	968,760.1
Receptacle				
Receptacles	511,120.0		3.4 %	1,533,513.1
Heating plant load				
Base Utilities			0.0 %	0.0
Cogeneration				
Cogeneration			0.0 %	0.0
Totals				
Totals**	13,608,400.0	1,242,134.0	100.0 %	42,136,788.0

* Note: Resource Utilization factors are included in the Total Source Energy value.
** Note: This report can display a maximum of 6 utilities. If additional utilities are used, they will be included in the total.

MONTHLY UTILITY COSTS

By ae

Alternative: 1

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Utility Costs -------								
Electric													
On-Pk Cons. ($)	100,425	90,928	110,798	85,904	92,713	95,632	84,777	95,129	82,169	95,539	98,789	93,221	1,126,023
Off-Pk Cons. ($)	101	101	101	101	101	101	101	101	101	101	101	101	1,207
Total ($):	100,525	91,028	110,898	86,005	92,814	95,733	84,877	95,230	82,269	95,639	98,889	93,322	1,127,230
Gas													
On-Pk Cons. ($)	650	595	676	321	126	123	35	62	84	248	520	505	3,944
Monthly Total ($):	101,175	91,623	111,574	86,326	92,940	95,855	84,912	95,291	82,353	95,887	99,410	93,827	1,131,174

ELECTRICAL PEAK CHECKSUMS

By ae

Alternative: 1   Palestra Building
Yearly Time of Peak: 9(Hr) 1(Month)

Equipment Description		Electrical Demand (kw)	Percent of Total (%)
Cooling Equipment			
Chiller 2		123.28	2.34
	Sub total	123.28	2.34
Heating Equipment			
Boiler 1		978.23	18.56
Boiler 2		978.23	18.56
Boiler 3		978.23	18.56
Boiler 4		978.23	18.56
	Sub total	3,912.92	74.24
Fan Equipment			
SUMMATION OF FAN ELECTRICAL DEMAND		1,225.63	23.25
SUMMATION OF FAN ELECTRICAL DEMAND		1,325.00	25.14
SUMMATION OF FAN ELECTRICAL DEMAND		400.00	7.59
SUMMATION OF FAN ELECTRICAL DEMAND		55.00	1.04
SUMMATION OF FAN ELECTRICAL DEMAND		55.00	1.04
	Sub total	3,060.63	58.06
Miscellaneous			
Lights		93.63	1.78
Base Utilities		0.00	0.00
Misc Equipment		140.61	2.67
	Sub total	234.24	4.45
	Total	7,331.07	139

YEARLY CASH FLOW

By ae

Alternative: 1
Life Cycle Cost: 28,947,790.94

Year	Utility Cost ($)	Maint. Cost ($)	Interest Cost ($)	Principal Cost ($)	Property Taxes ($)	Insurance Cost ($)	Revenue Penalty ($)	Replace. Expenses ($)	Deprec. Tax ($)	Cash Flow Effect ($)	Present Value ($)
0	0	0	0	17,826,732	0	0	0	0	0	17,826,732	17,826,732
1	1,131,174	306,000	0	0	0	0	0	0	891,337	971,472	844,758
2	1,131,174	367,200	0	0	0	0	0	0	891,337	1,020,432	771,593
3	1,131,174	440,640	0	0	0	0	0	0	891,337	1,079,184	709,581
4	1,131,174	528,768	0	0	0	0	0	0	891,337	1,149,687	657,337
5	1,131,174	634,522	0	0	0	0	0	0	891,337	1,234,289	613,660
6	1,131,174	761,426	0	0	0	0	0	0	891,337	1,335,813	577,509
7	1,131,174	913,711	0	0	0	0	0	0	891,337	1,457,641	547,981
8	1,131,174	1,096,453	0	0	0	0	0	0	891,337	1,603,835	524,296
9	1,131,174	1,315,744	0	0	0	0	0	0	891,337	1,779,267	505,779
10	1,131,174	1,578,893	0	0	0	0	0	0	891,337	1,989,786	491,845
11	1,131,174	1,894,671	0	0	0	0	0	0	891,337	2,242,409	481,991
12	1,131,174	2,273,605	0	0	0	0	0	0	891,337	2,545,556	475,783
13	1,131,174	2,728,326	0	0	0	0	0	0	891,337	2,909,333	472,848
14	1,131,174	3,273,992	0	0	0	0	0	0	891,337	3,345,866	472,867
15	1,131,174	3,928,790	0	0	0	0	0	0	891,337	3,869,704	475,565
16	1,131,174	4,714,548	0	0	0	0	0	0	891,337	4,498,311	480,711
17	1,131,174	5,657,457	0	0	0	0	0	0	891,337	5,252,638	488,106
18	1,131,174	6,788,949	0	0	0	0	0	0	891,337	6,157,831	497,584
19	1,131,174	8,146,739	0	0	0	0	0	0	891,337	7,244,063	509,006
20	1,131,174	9,776,086	0	0	0	0	0	0	891,337	8,547,541	522,257

TRACE® 700 Economic Summary

By ae

Project Information

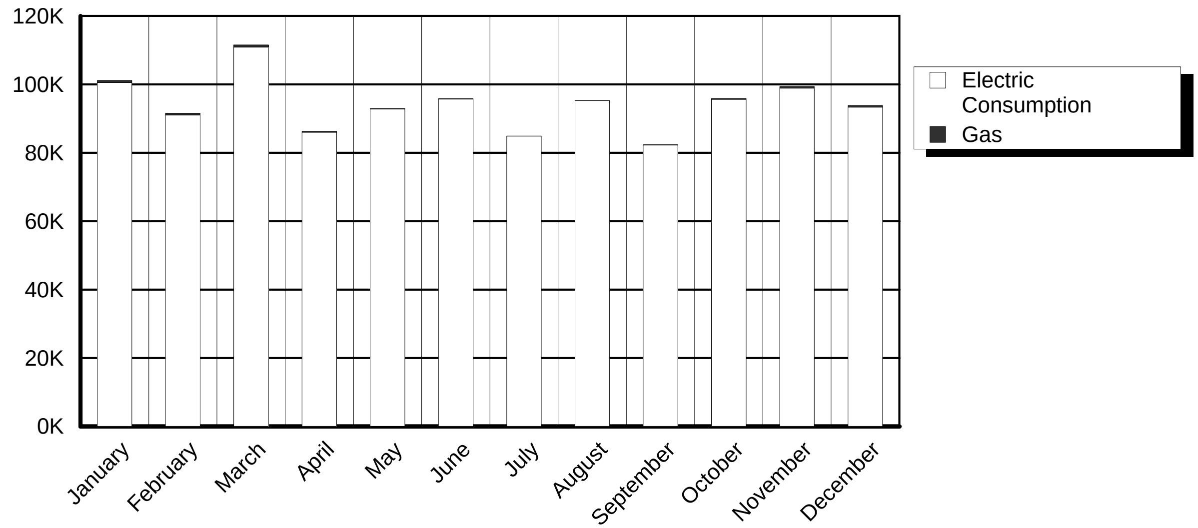
Weather file	Heathrow, England	Alternative 1 - - Palestra Building
Project Name		
Location	London, England	
Building Owner	Balckfriars Investment	
User		
Company	Penn State University	
Comments		

Economic Summary

Alternative Number	Installed Cost	First Year Util.Cost	Final Year Util. Cost	First Year Maint. Cost	Final Year Maint. Cost	Life Cycle Cost
1	17,436,428.00	1,131,174.34	1,131,174.34	306,000.00	9,776,086.14	28,581,917.36

Monthly Utility Costs per Utility

(1 alternative)



Equipment Energy Consumption by Alternative

	Elect Cons. (kWh)	Gas Cons. (kwh)	Percent of Total Energy	Total Source Energy* (kWh/yr)
Alternative: 1 - Palestra Building				
Primary heating	9,914.1	1,242,134.0	8.4%	1,337,254.8
Cooling Compressor	914,194.2		6.2%	2,742,856.8
Tower/Cond Fans	122,701.5		0.8%	368,141.3
Condenser Pump	73,749.0		0.5%	221,269.0
Other CLG Accessories	908.8		0.0%	2,726.7
Supply Fans	8,652,317.0		58.3%	25,959,544.0
Circ Pumps	3,000,608.5		20.2%	9,002,725.0
Lighting	322,887.8		2.2%	968,760.1
Totals	**13,608,400.0**	**1,242,134.0**	**100.0%**	**42,136,788.0**

* *Note: Resource Utilization factors are included in the Total Source Energy value.*

DOAS and Gas Engine Driven Chiller Plant Energy Simulation

MONTHLY ENERGY CONSUMPTION

By ae

Alternative: 1 Palestra Building

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	------- Monthly Energy Consumption -------												
Electric													
On-Pk Cons. (kWh)	1,134,612	1,027,392	1,259,927	961,879	1,043,115	1,080,925	928,984	1,070,529	918,740	1,077,373	1,117,477	1,048,064	12,669,017
On-Pk Demand (kW)	7,225	6,526	5,250	4,360	3,943	3,943	3,592	3,923	3,946	3,943	6,734	5,553	7,225
Gas													
On-Pk Cons. (kWh)	329,670	300,139	337,815	222,079	165,275	161,187	177,088	156,263	148,989	203,775	284,854	283,721	2,770,855
On-Pk Demand (kW)	4,068	3,166	2,998	1,675	1,114	1,143	752	671	1,092	1,522	3,330	2,705	4,068
Water													
Cons. (kL)	1,508	1,367	1,537	1,486	1,610	1,564	2,003	1,792	1,614	1,585	1,478	1,516	19,061

Building Energy Consumption = 4,982 MJ/(m2-year)
Source Energy Consumption = 13,207 MJ/(m2-year)
Floor Area = 11,158 m2

ENERGY CONSUMPTION SUMMARY

By ae

	Elect Cons. (kWh)	Gas Cons. (kwh)	Water Cons. (kL)	Percent of Total Energy	Total Source Energy* (kWh/yr)
Primary heating					
Primary heating	9,914.1	1,242,134.0		8.1 %	1,337,254.8
Primary cooling					
Cooling Compressor		1,528,721.5		9.9 %	1,609,180.4
Tower/Cond Fans	122,329.8		19,060.7	0.8 %	367,026.2
Condenser Pump	27,837.3			0.2 %	83,520.2
Other CLG Accessories	14,124.0			0.1 %	42,376.1
Cooling Subtotal....	164,291.1	1,528,721.5	19,060.7	11.0 %	2,102,103.0
Auxiliary					
Supply Fans	8,652,317.0			56.0 %	25,959,544.0
Circ Pumps	3,008,486.0			19.5 %	9,026,360.0
Base Utilities				0.0 %	0.0
Aux Subtotal....	11,660,803.0			75.5 %	34,985,904.0
Lighting					
Lighting	322,887.8			2.1 %	968,760.1
Receptacle					
Receptacles	511,120.0			3.3 %	1,533,513.1
Heating plant load					
Base Utilities				0.0 %	0.0
Cogeneration					
Cogeneration				0.0 %	0.0
Totals					
Totals**	12,669,016.0	2,770,855.5	19,060.7	100.0 %	40,927,536.0

* Note: Resource Utilization factors are included in the Total Source Energy value.
** Note: This report can display a maximum of 6 utilities. If additional utilities are used, they will be included in the total.

MONTHLY UTILITY COSTS

By ae

Alternative: 1

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Utility Costs -------								
Electric													
On-Pk Cons. ($)	93,883	85,021	104,241	79,606	86,320	89,446	76,887	88,586	76,040	89,152	92,467	86,729	1,048,377
Off-Pk Cons. ($)	101	101	101	101	101	101	101	101	101	101	101	101	1,207
Total ($):	93,984	85,121	104,342	79,706	86,421	89,546	76,987	88,687	76,141	89,252	92,567	86,830	1,049,584
Gas													
On-Pk Cons. ($)	1,047	953	1,073	705	525	512	562	496	473	647	905	901	8,799
Water													
On-Pk Cons. ($)	2,185	2,126	2,197	2,176	2,228	2,209	2,394	2,305	2,230	2,218	2,172	2,189	26,630
Monthly Total ($):	97,216	88,200	107,612	82,588	89,174	92,267	79,944	91,488	78,844	92,117	95,644	89,920	1,085,013

ELECTRICAL PEAK CHECKSUMS

By ae

Alternative: 1 Palestra Building
Yearly Time of Peak: 9(Hr) 1(Month)

Equipment Description		Electrical Demand (kw)	Percent of Total (%)
Cooling Equipment			
IC Chiller 1		16.83	0.33
IC Chiller 2		0.15	0.00
IC Chiller 3		0.15	0.00
IC Chiller 4		0.15	0.00
IC Chiller 5		0.15	0.00
	Sub total	17.43	0.33
Heating Equipment			
Boiler 1		978.23	18.93
Boiler 2		978.23	18.93
Boiler 4		978.23	18.93
Boiler 3		978.23	18.93
	Sub total	3,912.92	75.72
Fan Equipment			
SUMMATION OF FAN ELECTRICAL DEMAND		1,225.63	23.72
SUMMATION OF FAN ELECTRICAL DEMAND		1,325.00	25.64
SUMMATION OF FAN ELECTRICAL DEMAND		400.00	7.74
SUMMATION OF FAN ELECTRICAL DEMAND		55.00	1.06
SUMMATION OF FAN ELECTRICAL DEMAND		55.00	1.06
	Sub total	3,060.63	59.22
Miscellaneous			
Lights		93.63	1.81
Base Utilities		0.00	0.00
Misc Equipment		140.61	2.72
	Sub total	234.24	4.53

ELECTRICAL PEAK CHECKSUMS

By ae

Alternative: 1 Palestra Building
Yearly Time of Peak: 9(Hr) 1(Month)

Equipment Description		Electrical Demand (kw)	Percent of Total (%)
	Total	7,225.22	140

YEARLY CASH FLOW

By ae

Alternative: 1
Life Cycle Cost: 28,716,638.12

Year	Utility Cost ($)	Maint. Cost ($)	Interest Cost ($)	Principal Cost ($)	Property Taxes ($)	Insurance Cost ($)	Revenue Penalty ($)	Replace. Expenses ($)	Deprec. Tax ($)	Cash Flow Effect ($)	Present Value ($)
0	0	0	0	17,826,732	0	0	0	0	0	17,826,732	17,826,732
1	1,085,013	306,000	0	0	0	0	0	0	891,337	934,543	812,646
2	1,085,013	367,200	0	0	0	0	0	0	891,337	983,503	743,669
3	1,085,013	440,640	0	0	0	0	0	0	891,337	1,042,255	685,300
4	1,085,013	528,768	0	0	0	0	0	0	891,337	1,112,757	636,223
5	1,085,013	634,522	0	0	0	0	0	0	891,337	1,197,360	595,300
6	1,085,013	761,426	0	0	0	0	0	0	891,337	1,298,884	561,543
7	1,085,013	913,711	0	0	0	0	0	0	891,337	1,420,712	534,098
8	1,085,013	1,096,453	0	0	0	0	0	0	891,337	1,566,905	512,224
9	1,085,013	1,315,744	0	0	0	0	0	0	891,337	1,742,338	495,281
10	1,085,013	1,578,893	0	0	0	0	0	0	891,337	1,952,857	482,716
11	1,085,013	1,894,671	0	0	0	0	0	0	891,337	2,205,480	474,053
12	1,085,013	2,273,605	0	0	0	0	0	0	891,337	2,508,627	468,880
13	1,085,013	2,728,326	0	0	0	0	0	0	891,337	2,872,404	466,846
14	1,085,013	3,273,992	0	0	0	0	0	0	891,337	3,308,936	467,648
15	1,085,013	3,928,790	0	0	0	0	0	0	891,337	3,832,775	471,027
16	1,085,013	4,714,548	0	0	0	0	0	0	891,337	4,461,381	476,765
17	1,085,013	5,657,457	0	0	0	0	0	0	891,337	5,215,709	484,674
18	1,085,013	6,788,949	0	0	0	0	0	0	891,337	6,120,902	494,600
19	1,085,013	8,146,739	0	0	0	0	0	0	891,337	7,207,134	506,412
20	1,085,013	9,776,086	0	0	0	0	0	0	891,337	8,510,612	520,001

TRACE® 700 Economic Summary

By ae

Project Information

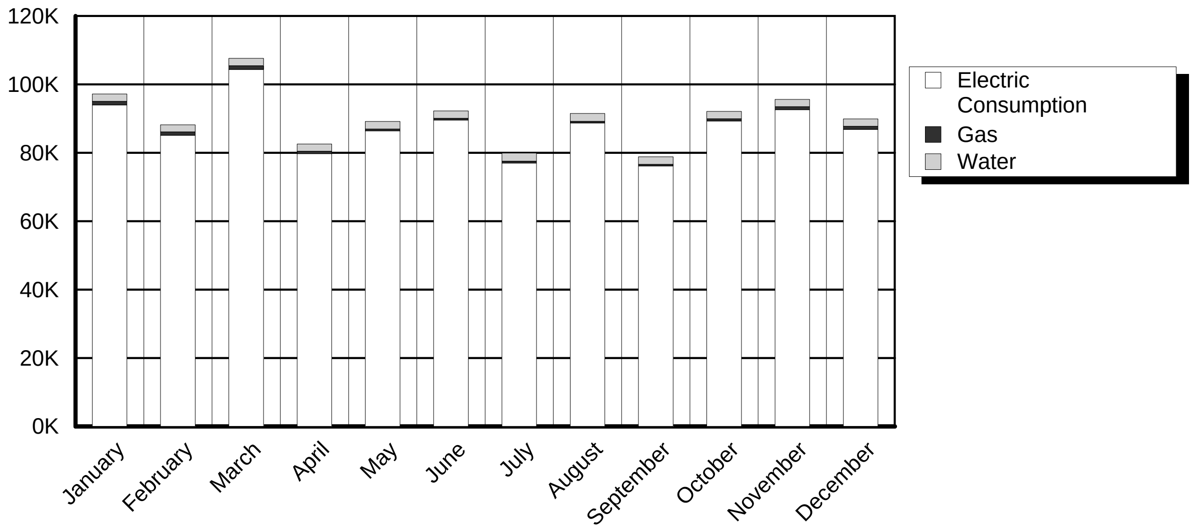
Weather file	Heathrow, England	Alternative 1 - - Palestra Building
Project Name		
Location	London, England	
Building Owner	Balckfriars Investment	
User		
Company	Penn State University	
Comments		

Economic Summary

Alternative Number	Installed Cost	First Year Util.Cost	Final Year Util. Cost	First Year Maint. Cost	Final Year Maint. Cost	Life Cycle Cost
1	17,722,422.00	1,085,012.70	1,085,012.70	306,000.00	9,776,086.14	28,618,857.23

Monthly Utility Costs per Utility

(1 alternative)



Equipment Energy Consumption by Alternative

	Elect Cons. (kWh)	Gas Cons. (kwh)	Water Cons. (liters)	Percent of Total Energy	Total Source Energy* (kWh/yr)
Alternative: 1 - Palestra Building					
Primary heating	9,914.1	1,242,134.0		8.1%	1,337,254.8
Cooling Compressor		1,528,721.5		9.9%	1,609,180.4
Tower/Cond Fans	122,329.8		19,060.7	0.8%	367,026.2
Condenser Pump	27,837.3			0.2%	83,520.2
Other CLG Accessories	14,124.0			0.1%	42,376.1
Supply Fans	8,652,317.0			56.0%	25,959,544.0
Circ Pumps	3,008,486.0			19.5%	9,026,360.0
Lighting	322,887.8			2.1%	968,760.1
Totals	**12,669,016.0**	**2,770,855.5**	**19,060.7**	**100.0%**	**40,927,536.0**

* *Note: Resource Utilization factors are included in the Total Source Energy value.*

APPENDIX E: Solar Energy Calculations

RETScreen® Solar Resource and System Load Calculation - Photovoltaic Project

Site Latitude and PV Array Orientation		Estimate	Notes/Range
Nearest location for weather data		London	See Weather Database
Latitude of project location	°N	51.5	-90.0 to 90.0
PV array tracking mode	-	Fixed	
Slope of PV array	°	30.0	0.0 to 90.0
Azimuth of PV array	°	0.0	0.0 to 180.0

Monthly Inputs

Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface (kWh/m²/d)	Monthly average temperature (°C)	Monthly average daily radiation in plane of PV array (kWh/m²/d)	Monthly solar fraction (%)
January	1.00	0.56	3.9	0.98	-
February	1.00	1.10	3.9	1.50	-
March	1.00	2.07	6.1	2.48	-
April	1.00	3.04	7.8	3.28	-
May	1.00	4.12	11.1	4.17	-
June	1.00	4.99	14.4	4.90	-
July	1.00	4.38	16.7	4.35	-
August	1.00	3.62	16.7	3.82	-
September	1.00	2.71	13.9	3.18	-
October	1.00	1.56	10.6	2.11	-
November	1.00	0.81	6.7	1.24	-
December	1.00	0.47	5.6	0.89	-

		Annual	Season of use
Solar radiation (horizontal)	MWh/m²	0.90	0.90
Solar radiation (tilted surface)	MWh/m²	1.00	1.00
Average temperature	°C	9.8	9.8

Load Characteristics		Estimate
Application type	-	On-grid

Return to Energy Model sheet

RETScreen® Cost Analysis - Photovoltaic Project

Type of analysis: Pre-feasibility | Currency: £ | Cost references: None

Initial Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
Feasibility Study							
Other - Feasibility study	Cost	0	£ 10,000	£ -		-	-
Sub-total :				**£ -**	0.0%		
Development							
Other - Development	Cost	0	£ 15,000	£ -		-	-
Sub-total :				**£ -**	0.0%		
Engineering							
Other - Engineering	Cost	0	£ 55,000	£ -		-	-
Sub-total :				**£ -**	0.0%		
Energy Equipment							
PV module(s)	kWp	24.80	£ 5,750	£ 142,600		-	-
Transportation	project	0	£ -	£ -		-	-
Other - Energy equipment	Cost	0	£ -	£ -		-	-
Credit - Energy equipment	Credit	0	£ -	£ -		-	-
Sub-total :				**£ 142,600**	50.0%		
Balance of Equipment							
Module support structure	m^2	195.3	£ 100	£ 19,528		-	-
Inverter	kW AC	72.0	£ 1,000	£ 72,000		-	-
Other electrical equipment	kWp	24.80	£ -	£ -		-	-
System installation	kWp	24.80	£ 1,500	£ 37,200		-	-
Transportation	project	0	£ -	£ -		-	-
Other - Balance of equipment	Cost	0	£ -	£ -		-	-
Credit - Balance of equipment	Credit	0	£ -	£ -		-	-
Sub-total :				**£ 128,728**	45.1%		
Miscellaneous							
Training	p-h	6	£ 65	£ 390		-	-
Contingencies	%	5%	£ 271,718	£ 13,586		-	-
Sub-total :				**£ 13,976**	4.9%		
Initial Costs - Total				**£ 285,303**	100.0%		

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Property taxes/Insurance	project	0	£ -	£ -		-	-
O&M labour	p-h	16	£ 55	£ 880		-	-
Other - O&M	Cost	0	£ -	£ -		-	-
Credit - O&M	Credit	0	£ -	£ -		-	-
Contingencies	%	0%	£ 880	£ -		-	-
Sub-total :				**£ 880**	100.0%		
Annual Costs - Total				£ 880	100.0%		

Periodic Costs (Credits)		Period	Unit Cost	Amount	Interval Range	Unit Cost Range
Inverter Repair/Replacement	Cost	12 yr	£ 50,000	**£ 50,000**	-	-
			£ -	**£ -**	-	-
			£ -	**£ -**	-	-
End of project life		-	£ -	**£ -**	*Go to GHG Analysis sheet*	

RETScreen® Energy Model - Photovoltaic Project

Training & Support

Site Conditions		Estimate	Notes/Range
Project name		**Palestra Building**	See Online Manual
Project location		**London, England**	
Nearest location for weather data	-	London	Complete SR&SL sheet
Latitude of project location	°N	51.5	-90.0 to 90.0
Annual solar radiation (tilted surface)	MWh/m²	1.00	
Annual average temperature	°C	9.8	-20.0 to 30.0

System Characteristics		Estimate	Notes/Range
Application type	-	**On-grid**	
Grid type	-	Isolated-grid	
PV energy absorption rate	%	95.0%	
PV Array			
PV module type	-	mono-Si	
PV module manufacturer / model #		BP Solar/ BP 5160 S	See Product Database
Nominal PV module efficiency	%	12.7%	4.0% to 15.0%
NOCT	°C	45	40 to 55
PV temperature coefficient	% / °C	0.40%	0.10% to 0.50%
Miscellaneous PV array losses	%	5.0%	0.0% to 20.0%
Nominal PV array power	kWp	**24.80**	
PV array area	m²	195.3	
Power Conditioning			
Average inverter efficiency	%	90%	80% to 95%
Suggested inverter (DC to AC) capacity	kW (AC)	22.3	
Inverter capacity	kW (AC)	72.0	
Miscellaneous power conditioning losses	%	0%	0% to 10%

Annual Energy Production (12.00 months analysed)		Estimate	Notes/Range
Specific yield	kWh/m²	102.4	
Overall PV system efficiency	%	10.2%	
PV system capacity factor	%	9.2%	
Renewable energy collected	MWh	23.386	
Renewable energy delivered	MWh	**19.995**	
	kWh	19,995	
Excess RE available	MWh	**1.052**	
			Complete Cost Analysis sheet

RETScreen® Financial Summary - Photovoltaic Project

Annual Energy Balance

Project name		Palestra Building			
Project location		London, England	Nominal PV array power	kWp	24.80
Renewable energy delivered	MWh	19.995			
Excess RE available	MWh	1.052			
Firm RE capacity	kW	-			
Application type		On-grid			

Financial Parameters

Avoided cost of energy	£/kWh	0.858	Debt ratio	%	60.0%
RE production credit	£/kWh	0.750	Debt interest rate	%	8.5%
RE production credit duration	yr	25	Debt term	yr	25
RE credit escalation rate	%	2.0%			
			Income tax analysis?	yes/no	No
Avoided cost of excess energy	£/kWh	-			
Energy cost escalation rate	%	5.0%			
Inflation	%	2.5%			
Discount rate	%	9.0%			
Project life	yr	25			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	0.0%	£	-	O&M	£	880
Development	0.0%	£	-	Fuel	£	-
Engineering	0.0%	£	-	Debt payments - 25 yrs	£	16,726
Energy equipment	50.0%	£	142,600	**Annual Costs and Debt - Total**	**£**	**17,606**
Balance of equipment	45.1%	£	128,728			
Miscellaneous	4.9%	£	13,976	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**£**	**285,303**	Energy savings/income	£	17,156
Incentives/Grants		£	-	RE production credit income - 25 yı	£	14,996
				Annual Savings - Total	**£**	**32,152**
Periodic Costs (Credits)						
Inverter Repair/Replacement		£	50,000	Schedule yr # 12,24		
		£	-			
		£	-			
End of project life -		£	-			

Financial Feasibility

			Calculate energy production cost?	yes/no	No
Pre-tax IRR and ROI	%	18.3%			
After-tax IRR and ROI	%	18.3%			
Simple Payback	yr	9.1			
Year-to-positive cash flow	yr	6.1	Project equity	£	114,121
Net Present Value - NPV	£	125,778	Project debt	£	171,182
Annual Life Cycle Savings	£	12,805	Debt payments	£/yr	16,726
Benefit-Cost (B-C) ratio	-	2.10	Debt service coverage	-	1.94

Yearly Cash Flows

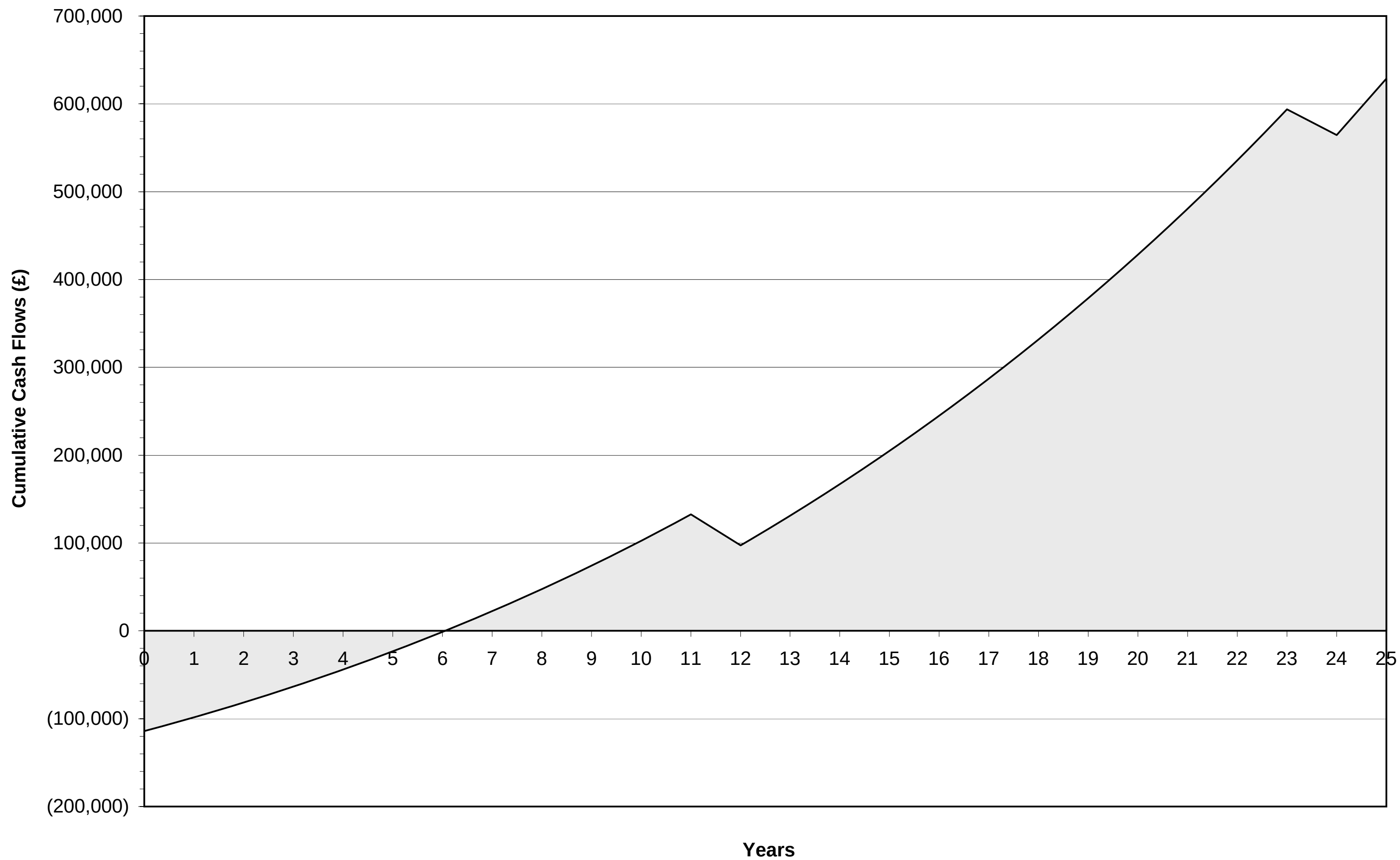
Year #	Pre-tax £	After-tax £	Cumulative £
0	(114,121)	(114,121)	(114,121)
1	15,681	15,681	(98,440)
2	16,865	16,865	(81,575)
3	18,100	18,100	(63,475)
4	19,388	19,388	(44,087)
5	20,731	20,731	(23,357)
6	22,132	22,132	(1,225)
7	23,593	23,593	22,368
8	25,119	25,119	47,487
9	26,711	26,711	74,198
10	28,372	28,372	102,570
11	30,107	30,107	132,677
12	(35,326)	(35,326)	97,351
13	33,809	33,809	131,160
14	35,785	35,785	166,945
15	37,848	37,848	204,792
16	40,003	40,003	244,795
17	42,254	42,254	287,049
18	44,607	44,607	331,656
19	47,065	47,065	378,721
20	49,635	49,635	428,356
21	52,320	52,320	480,676
22	55,128	55,128	535,803
23	58,063	58,063	593,866
24	(29,305)	(29,305)	564,561
25	64,340	64,340	628,902

RETScreen® Financial Summary - Photovoltaic Project

Cumulative Cash Flows Graph

Photovoltaic Project Cumulative Cash Flows
Palestra Building, London, England

Renewable energy delivered (MWh/yr): 19.995 **Total Initial Costs: £ 285,303**



IRR and ROI: 18.3% **Year-to-positive cash flow: 6.1 yr** **Net Present Value: £ 125,778**

Solar PV Panel Specifications

BP Solar BP 5160 S/L

Manufacturer	**BP Solar**
Name	**BP 5160 S/L**

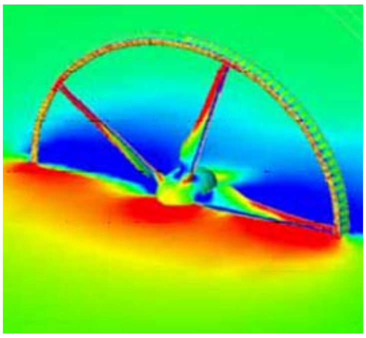
Technical specifications

Nominal output	160 watt
Max. panel voltage	1000 V
Length	1596 mm
Width	790 mm
Height	0 mm
Short circuit current	4.7 A
Max. panel voltage	1000 V
MPP voltage	36 V
MPP current	4.44 A
Temperature coefficent off-load voltage	-160 mV / °C
Temperature coefficent MPP voltage	-160 mV / °C
	Quality of data ★★★

Description

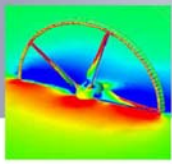
APPENDIX F:
Wind Energy Data

Technical Information Pack



SWIFT

Rooftop Wind Energy System™

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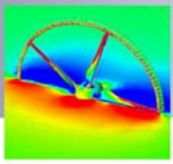


1. SWIFT Rooftop Wind Energy System™

1.1 Introduction

This document is intended to provide guidance to engineers, architects and specifiers, when considering the installation of a SWIFT Rooftop Wind Energy System™. It is not intended as an Installation Manual and does not contain information suitable for the maintenance, installation or decommissioning of the SWIFT Rooftop Wind Energy System™.

The system must ONLY be installed by trained and approved installers.

The information contained in this document is subject to periodic review and it is the specifiers' responsibility to ensure that the most recent version is utilised.

1.2 Product Description

As part of its mission to provide accessible renewable technologies, Renewable Devices Swift Turbines Ltd (RDSTL) has produced the world's first feasibly rooftop-mountable wind turbine, capable of providing a cost effective renewable energy source for domestic, community and industrial use. The SWIFT Rooftop Wind Energy System™ is grid connected for "beyond the meter" generation.

The emphasis of the design process has focused on safety, reliability and ease of operation, alongside high performance of this innovative system. The turbine uses unique patented technologies, which allow:

- Wide ranging application
- Vibration-isolated rooftop mounting
- Quiet operation through acoustic suppression aerodynamics
- Safe, efficient & autonomous operation
- Visually appealing design
- Environmentally sustainable "harm neutral" design; allowing the SWIFT™ to become carbon and energy positive within four years.
- Sophisticated electronic control system

The SWIFT™ turbine is mounted on a bespoke aluminium mast with a minimum blade-roof clearance of 0.5 metres. It is usually optimally mounted at the highest point of a roof in a position that benefits from maximum prevailing wind.

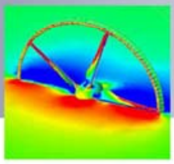
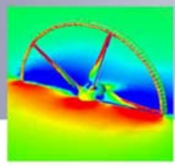


Figure 1 - Installed SWIFT Rooftop Wind Energy System™

To ensure minimal transmission of oscillations from turbine to building, the mounting brackets incorporate damping systems, designed to isolate at a wide range of frequencies. The patented ring diffuser around the rotor blades is designed to minimise turbine noise by preventing the creation of violent vortices at the blade tip. In addition the five-bladed design allows for a slower speed of rotation further reducing noise, making the SWIFT Rooftop Wind Energy System™ the quietest wind system currently available.

The SWIFT™ turbine has a unique over-power regulation mechanism to control rotation speed and maintain system integrity/safety in high winds. This consists of an innovative twin-vane progressive mechanical furling mechanism, coupled with a sophisticated electronic control system. This allows the optimum amount of power to be extracted from the turbine under varying wind and loading conditions, representing a step change in the accurate and safe control of small wind turbines.

In environmental terms, each unit of electricity generated from a SWIFT Rooftop Wind Energy System™ displaces one unit generated from fossil fuels, with the added benefit that the electricity is consumed on-site, thus negating losses from transmission. This can amount to a displacement of up to 1.4 tonnes of CO_2 per year – a significant environmental contribution.



2. Planning Policy

2.1 Policy and legislative context

The Scottish Executive's policy for renewable energy is described in PAN 45 and is set out in "NPPG6, Renewable Energy Developments". UK policy encourages the uptake of widespread micro generation including rooftop wind turbines such as the SWIFT Rooftop Wind Energy System™ on domestic, educational and industrial premises. Indeed the Energy Minister Malcolm Wicks expressed his support during a speech at a Green Conference in his constituency in October 2005: "Imagine one day, every school with its own micro wind turbine and/or state of the art solar paneling. Imagine a clear display panel on such a school detailing how much carbon dioxide has been saved. Imagine how the science teacher, or those teaching citizenship responsibilities, could use such technology in their teaching…"

2.2 Technology Overview

The need for increased use of renewable energy is well established. Opportunities to generate 'bulk' electricity from renewable resources are currently being exploited throughout Europe, including the development of wind, hydro and other technologies.

It is recognised however, that in order to both meet objectives for CO_2 reductions and decrease our dependency on fossil fuels, domestic and commercial application of renewable technologies must be increased. Small-scale wind turbines have the potential to contribute towards this, providing electricity or hot water heating in both domestic and commercial applications. The associated CO_2 savings per turbine contribute to the UK's CO_2 emissions reduction targets and longer term cost savings per household or business can be significant. In addition wide deployment of turbines will lead to significant CO_2 savings in the longer term and will increase levels of 'embedded' generation.

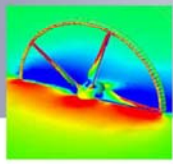
2.3 Visual impact

Rooftop-mounted small wind turbines will be installed in a position to take advantage of higher wind speeds on the top of building structures (with the exception of 'building integrated' designs) and will be comparable in height to a large television aerial or chimney stack. The SWIFT™ has been designed to comply with planning requirements and to complement the aesthetics of a building. As with satellite dishes, rooftop wind turbines are now becoming more widely accepted with increasing familiarity.

Applications should be assessed on a case-by-case basis, taking account of the existing building/structures, relative scale, nature of the setting and benefits of renewable energy generation. Computer generated photo montages of buildings with superimposed in-situ turbines can be used to assist the planning process. The colour and finish of the SWIFT Rooftop Wind Energy System™ is designed to minimise visual impact and reflection of light.

Due to the fact that SWIFT™ turbines will be located on or near existing commercial/domestic buildings, they will not add a significant new visual element to the local landscape. Unlike large wind farm installations, a full landscape and visual impact assessment is not required.

Free standing SWIFTs™ mounted on masts (as opposed to being building mounted) should also be assessed on a case-by-case basis, in accordance with guidance contained in the main planning annex on wind energy and any additional structural/engineering issues.



2.4 Noise

The need to control noise emissions from a small-scale wind turbine is critical in domestic settings. In commercial/light industrial settings, where there are no residential properties in the immediate vicinity, the control of noise is important, but less critical. Detailed discussion of noise from wind turbines is contained in the main wind energy appendix to "PAN 45 (revised 2002): Renewable Energy Technologies", and wider discussion of planning and noise can be found in PAN 56.

In the absence of specific guidance on noise for small-scale wind turbines, they should meet the criteria identified by the DTI/ETSU report: 'The Assessment and Rating of noise from wind farms.'[1]. As a general rule, noise emitted from the turbine should not exceed 5dB(a) above background noise, with a fixed limit of 43dB(A) recommended for night time. Both day and night time noise limits can be increased to 45dB(A) where the owner of the property benefits directly from the operation of the turbine. The SWIFT Rooftop Wind Energy System™ always emits less than 35dB(A,) across all wind speeds and therefore meets all legislative criteria.

The SWIFT™ has been designed to comply with these regulations and there is no evidence to suggest that SWIFT Rooftop Wind Energy Systems™ have any detrimental effect on wildlife.

2.5 Reflectivity and Reflection

To minimise the occurrence of 'flash' the SWIFT's™ rotor is comprised of moulded carbon fibre, with a matt black surface. Matt is specifically chosen to avoid highlights or bright reflections from rotor surfaces during rotation, in either natural or artificial light. The black colour allows for minimal reflectivity (the ratio of the total amount of white light diffusely reflected by the surface to the amount falling on the surface) as it is extremely absorptive over a wide range of wavelengths.

In addition, the small diameter and likely location of the turbine ensures that reflection and reflectivity are not considered to be issues for the SWIFT Rooftop Wind Energy System™.

2.6 Electromagnetic Interference

Aircraft, Military Low Flying, Aerodromes and technical sites:

Unlike large wind turbines and wind farms, small SWIFT™ rooftop wind turbines are extremely unlikely to cause any detrimental effects on aviation and associated radar/navigation systems. They have been successfully installed near major airports without any negative effects on aviation.

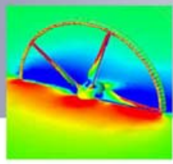
Television / radio reception:

The SWIFT Rooftop Wind Energy System™ meets all of the mandatory UK and EU Electro-Magnetic Compatibility (EMC) standards and does not affect television or radio reception.

Effect on mobile phone and telecommunications links:

The SWIFT Rooftop Wind Energy System™ meets all of the requisite UK and EU Electro-Magnetic Compatibility (EMC) standards and does not effect mobile phone reception or fixed radio/microwave communications links.

[1] ETSU (1996) 'The Assessment and Rating of noise from wind farms.' DTI Noise Working Group, Energy Technology Support Unit.



Emission of electromagnetic radiation:

The SWIFT Rooftop Wind Energy System™ has been fully EMC tested for electro-magnetic compatibility and exceeds all of the relevant UK and European standards (BS EN 61000-6-3: 2001 EMC Emissions and BS EN 61000-6-1: 2001 EMC Immunity, both of which are relevant for residential, commercial and light industry).

2.7 Bird Strike

The transparency of the SWIFT's™ five rotating blades is much less than that of a window and this combined with the solid diffuser ensures that the turbine remains a clearly defined unit at all times. The small diameter of the SWIFT™ rotor (~2m) makes it comparable as an obstacle to a rooftop television aerial, satellite dish or chimney stack. It is extremely unlikely therefore, that the location of a rooftop turbine will cause a significant increase in bird strike, beyond the rates already caused by existing buildings, windows and other such obstacles. During a twelve month in situ testing program on a single storey structure, not a single bird collision was recorded, neither have any been reported from turbines installed throughout the UK to date.

All accredited installers are advised to enquire as to the location of localised nesting areas and carry out subsequent installations with the minimum of disturbance, in line with regulations of the Wildlife and Countryside Act 1981 (WCA) and Countryside and Rights of Way Act 2000 (CROW Act - specifically in England and Wales).

The sixteen species of bats in the United Kingdom are virtually all classified as rare, vulnerable or endangered and as such both bats and their roosts are also protected by the afore mentioned WCA 1981 and CROW Act 2000; the regulations of which SWIFT™ installations strictly adhere to.

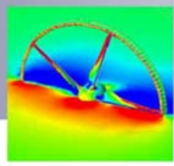
The RSPB views climate change as the most serious long-term threat to wildlife, both globally and in the UK. They subsequently support the deployment of wind turbines, both large and small, provided they are positioned sensitively with care and consideration shown for the local flora, fauna and wildlife.

2.8 Safety

Structural safety:
The SWIFT™ has been designed and independently tested to ensure compliance with all mandatory product standards of the IEC 61400 and in particular, BS EN 61400-2: 1995 "Wind turbine generator systems - safety requirements".

The SWIFT Rooftop Wind Energy System™ is designed to withstand extremely high winds and will typically shut down or 'furl out' in high wind speeds to protect the turbine from damage. The SWIFT™ is designed (and has been independently verified) to meet and exceed all of the structural and safety constraints required by BS EN 61400-2 and all other UK safety standards for machines of this type. Electrical connections and/or an associated hot water system should be installed in accordance with appropriate building standards.

Electro-magnetic compatibility:
The SWIFT™ complies with BS EN 61000-6-3: 2001and BS EN 61000-6-1: 2001 for domestic, commercial & industrial premises (power quality) effects including flicker and harmonic distortion.



Electrical safety:
The SWIFT Rooftop Wind Energy System™ meets all of the electrical safety criteria set out in EN 50178 and the 16th Edition of the UK Wiring Regulations.

Grid monitoring:
The SWIFT Rooftop Wind Energy System™ meets all of the grid-monitoring criteria set out in VDE 126, including Anti-Islanding Protection.

G83 compliance
The SWIFT Rooftop Wind Energy System™ has been independently verified to ensure that it meets the G83 standard for the grid-connection of small-scale generators.

CE Marking
The SWIFT™ Rooftop Wind Energy System™ meets all appropriate European Directive legislation and is certified as CE compliant.

2.9 Versatility

The SWIFT Rooftop Wind Energy System™ can be installed safely and simply into almost any building design. Single or multiple installations are both equally possible, as are installations on both residential and commercial properties.



Figure 2 – SWIFT™ installations

3. Installation summary

For information only, below are the steps required to achieve a safe and effective installation of the SWIFT Rooftop Wind Energy System™:

The system must ONLY be installed by trained and approved installers.

- Transportation and receipt of SWIFT Rooftop Wind Energy System™.
- Preparation of walls and installation of mounting brackets.
- Installation of turbine mounting mast.
- Installation of electronic control system and grid-tie inverter.
- Installation of SWIFT™ turbine.
- Electrical connection of system.
- Testing.
- Commissioning.
- Completion of test certificates and commissioning documentation.

The SWIFT™ turbine is typically wall-mounted at the gable end of a building using the bespoke brackets supplied (figure 3). For information, the bracket spacing is as shown in figure 4, below.

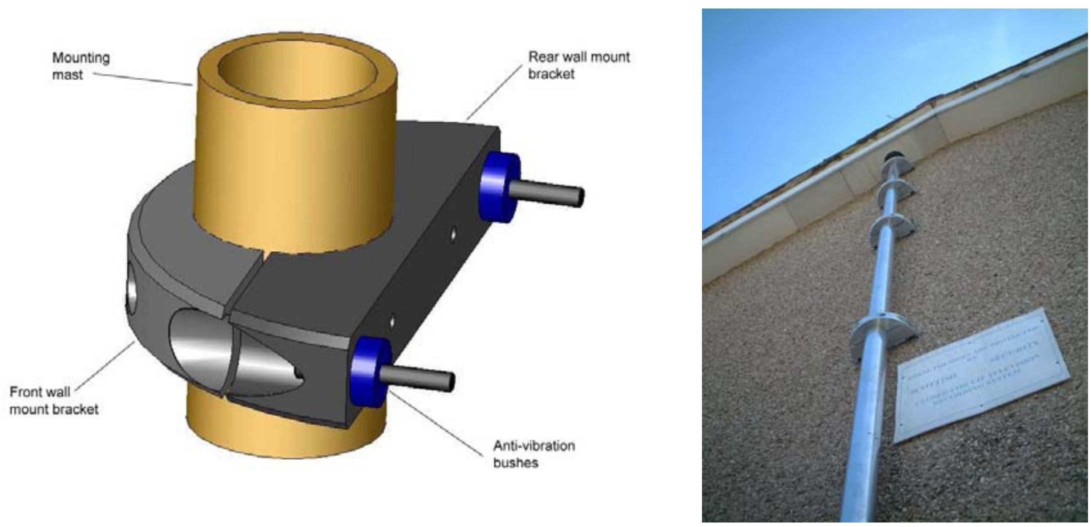
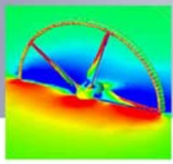


Figure 3 - Correctly assembled & installed mast mounting brackets

The pitch of the holes required to mount there brackets to the wall or any reinforcing structure is 254.0mm.



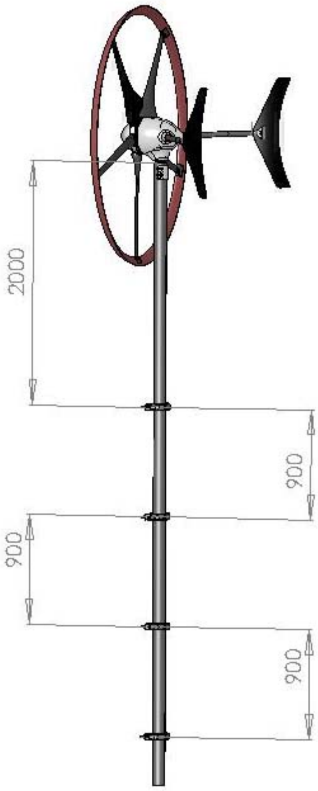
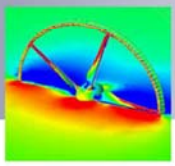


Figure 4 - SWIFT™ wind turbine assembly showing bracket spacings

In some circumstances it may be necessary to mount the SWIFT™ wind turbine mounting mast onto the exterior, and through the overhanging eaves of a building. In this instance, sealing roof glands will be required. The mounting mast is located by sliding it up through these rubber glands.

Figure 5 - Typical installation of rubber roof gland seal.



3.1 Flat Roof Installation

The SWIFT Rooftop Wind Energy System™ can also be installed on a flat roof. In this type of installation, the mounting mast described above is replaced with a bespoke mounting stand. The installation of this stand is site-specific and may require additional engineering work to be carried out in order to assess/ensure the structural suitability of the building.

The most common type of flat roof installation uses a bespoke stand, as shown in Figure 6.

Figure 6 - A typical flat roof installation configuration

The height of the flat roof mounting mast will vary as some sites may have a parapet. The flat roof mounting mast will be between 1.5m and 3.5m in height (from the base plate to the turbine hub height) and will typically be 2.0m.

For reference, the approximate mass of the SWIFT™ turbine components are as follows:

Mass of SWIFT™ turbine:	50 kg
Mass of mounting mast:	40 kg

3.2 Loadings

In all installation configurations, the wall mounting anchors or the flat roof stand will transmit the aerodynamic thrust from the rotor to the mounting structure. The amount of mechanical stress imposed on the anchors will depend on the height of the mounting mast – each installation is different. As a guide, when designing the mounting structure, the stress at the anchor points should be considered to be induced by an axial thrust (acting horizontally at the rotor hub height) of 7kN, plus the loads due to the mass of the turbine and mounting masts.

4. Electrical & electronic controller connections

The SWIFT Rooftop Wind Energy System™ will be supplied with two electronic components: an electronic control system and a grid-tie inverter.

The electronic control system provides sophisticated electronic control of the turbine and includes a manual brake to allow for safe access near the installation etc. The grid-tie inverter is used to synchronise the power output to that of the consumers' electricity supply.

Figure 7 - Installed SWIFT™ Electronic Control System

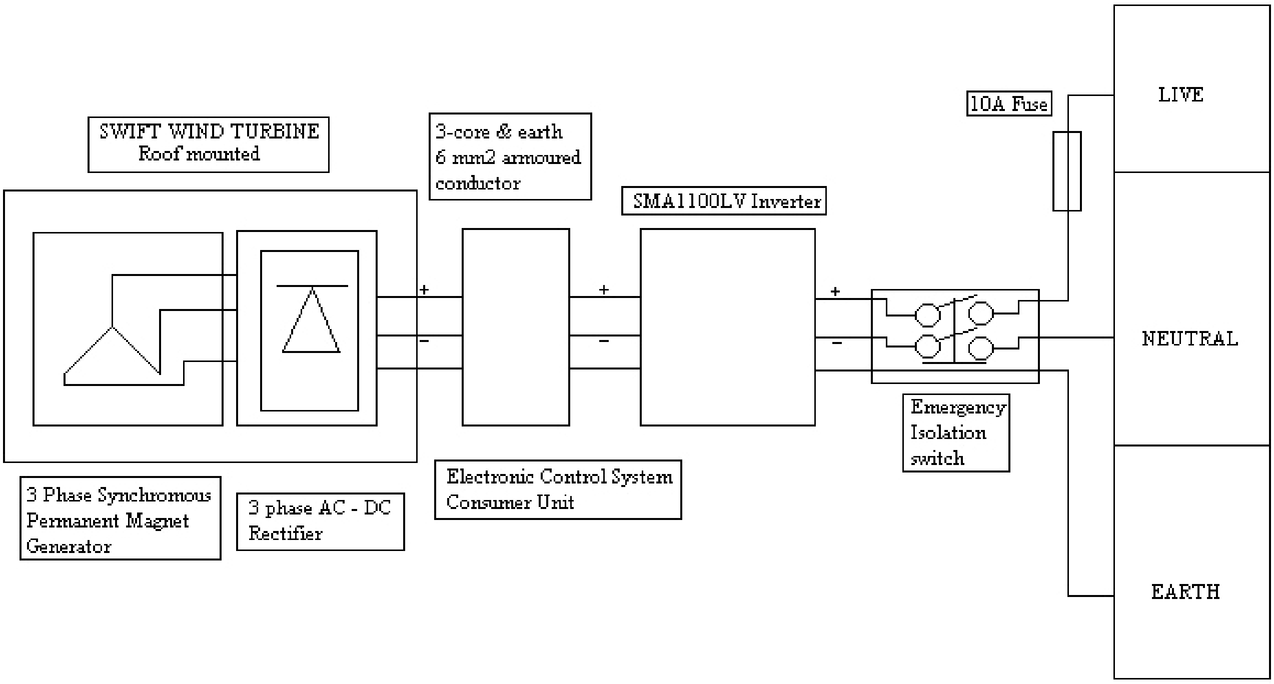
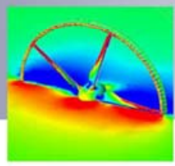


Figure 8 - Electrical Schematic of a typical installation



5. Performance

The power curve for the SWIFT Rooftop Wind Energy System™ is shown in figure 9, below.

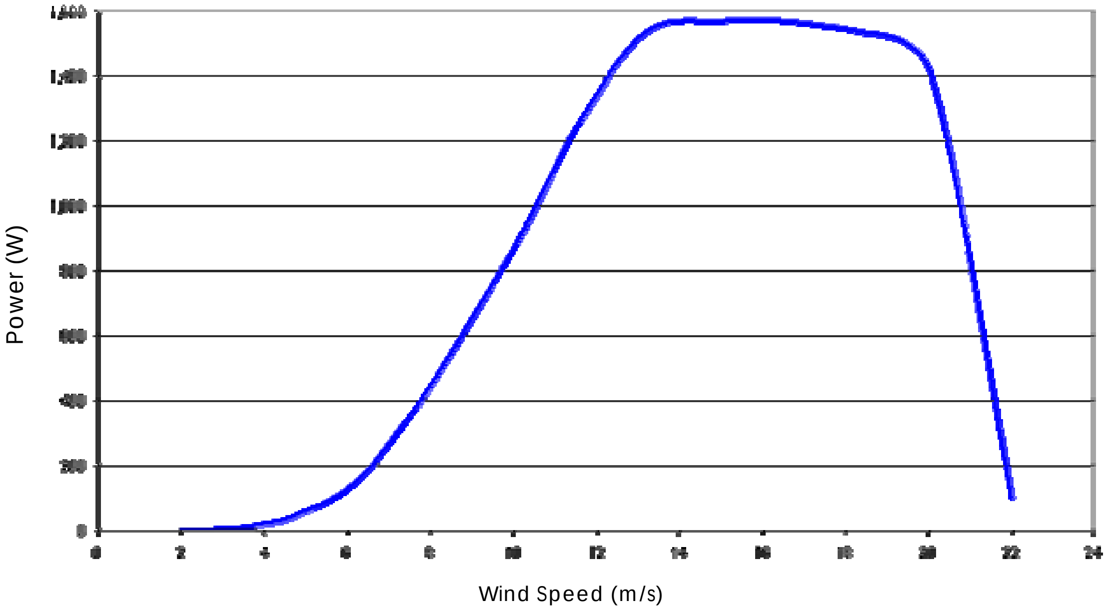


Figure 9 - SWIFT™ power curve

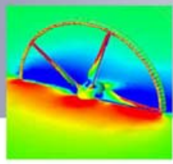
6. Compliance

The SWIFT Rooftop Wind Energy System™ has been independently tested and certified to comply with the following standards and directives:

EN 61400-2: 1996
This standard relates to the safety of wind turbine generator systems and is applied as the SWIFT Rooftop Wind Energy System™ has a swept rotor area of less than $40m^2$ and generates at a voltage below 1,000 V, a.c. or 1,500 V, d.c. Mechanical components are designed and specified to meet this standard. Apart from EMC, described below, the specific electrical standard applied to satisfy EN 61400-2 is EN 60950.

EN 61400-24: 1996
Lightening protection of wind turbines.

EN 60950: 2000
The SWIFT™ turbine operates at safety extra low voltage (SELV), below the threshold voltage at which the low-voltage directive is normally applicable. However, EN 60950 is applied as a standard for safety aspects other than the risk of electric shock. These include flammability of component parts, temperature rise of user-accessible components, labelling and accompanying documents.



BS 5760-0:1986
Although BS 7671 deals with electrical installations, component parts of the SWIFT Rooftop Wind Energy System™ are designed to facilitate its installation in accordance with this standard.

BS EN 61000-3-2 and BS EN 61000-3-3
Electro-magnetic compatibility limits for harmonic distortion & voltage fluctuation.

EN 50081-1
Electro-magnetic compatibility - domestic, commercial and light industrial premises.

EN 50081-2
Electro-magnetic compatibility - industrial premises.

EN 61000
Mains frequency (power quality) effects including flicker and harmonic distortion.

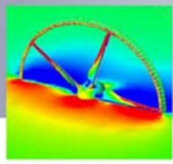
VDE 126
For the safety of Grid Monitoring (Including Anti-Islanding Protection).

IEE 16th Edition Wiring Regulations BS7671
For the safety of domestic electrical installations.

Electricity Association, Engineering Recommendation G59
Electricity Association (since 1 October 2003 superseded by Energy Networks Association). Grid connection of embedded generators at <5MW and <20kV.

Electricity Association, Engineering Recommendation G83/1
Electricity Association (since 1 October 2003 superseded by Energy Networks Association). Grid connection of embedded generators up to 16A per phase (supersedes G77).

BS 5080-1: 1993
The structural fixings used to attach the SWIFT™ system to a concrete substrate are tested in compliance with BS 5080-1: 1993.



7. Technical Specification

Rated power output: 1.5kW *

Approx. annual power supplied: 2000-3000kWh **

1.4 Tonnes of CO_2 reduction/annum ***

Planning Compliant Design

Acoustic emission < 35dB(A)

Moulded carbon-fibre rotor (fail safe)

EMI suppression technology

Embedded electrical connection

Direct Water Heating

Compact design

5-blade HAWT wind turbine

Rotor diameter 2.12m (6.5 feet)

Product Life: 20 years

Mounting mast (BS1387, ISO65)

EMC directive compliant

LVD directive complaint

CE marked

Low maintenance

Single or multiple installation

Safety systems comply with International Standard IEC 1400-1 & BS EN 61400-2

Electricity Association Requirement G59, G77and G83 compliant

BS 7671 :16th Edition of the IEE Wiring Regulations

BS 5760-7: Reliability of Systems, Equipment and Components

The SWIFT Rooftop Wind Energy System™ is mounted on a bespoke mast with a minimum blade-roof clearance of approximately 0.5 metres. It has a novel over-power regulation mechanism, which is totally passive and maintains its tip speed ratio across its entire operating envelope. The turbine has a novel twin-vane progressive furling mechanism which maintains the systems integrity and safety in high winds. It will operate automatically around the clock.

* Rated wind speed: 12.5m/s
** Dependant on siting of turbine
*** Substituting end-user electricity with a single 1.5kW rooftop turbine at 30% utilization by CEDRL RETScreen® International).

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