

University of Wales Trinity Saint David

MSc Property & Facilities Management

Building Services & Energy Audit

Services & Energy Performance of Buildings –
M7X01813

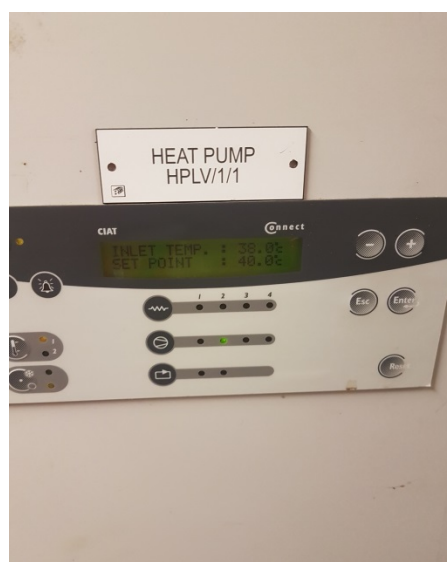
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Optometry & Vision Sciences Building, Cardiff – Asset Schedule

The Optometry Building has two main Plant Rooms at basement level, accessed from steps leading down from ground level pavement.

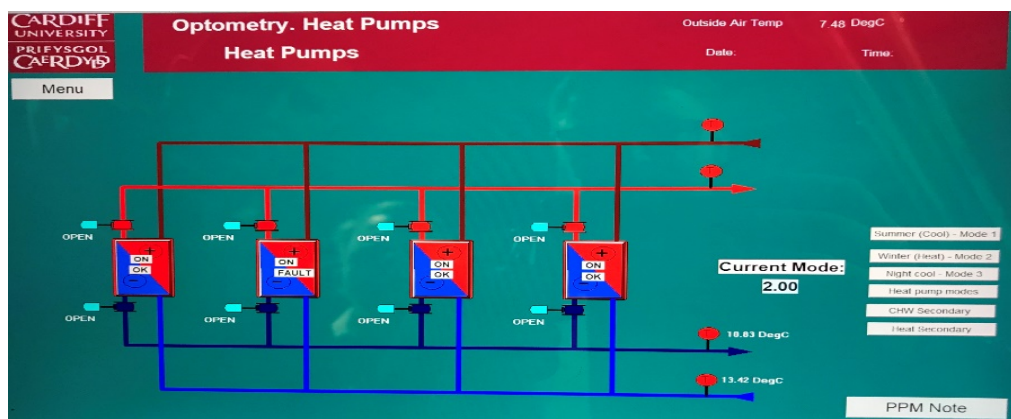
The primary source of heating for the building is generated from 4no HydroCIAT Ground Source Heat pumps (GSHP's).



These are fitted with CIAT 'Connect' controllers and are linked into the Building Management System (BMS). The GSHP's provide underfloor heating to parts of the building, as well as feeding fan coil units with heating and cooling from the four pipe system installed.

The GSHP's are fed from 56 boreholes at an approx. depth of between 100-120m on a closed loop vertical system.

Energy Manager Mark Durdin stated during the site visit that the quantity of GSHP's was possibly over specified and that 3no. would cope adequately with the service demand. At the time of the inspection one heat pump appeared to be isolated, but it was not clear if this was due to a maintenance issue.



There are a twin set of Grundfos MG Primary & Secondary Heating pumps and 2no twin sets on the Primary and Secondary Cooling pumps.

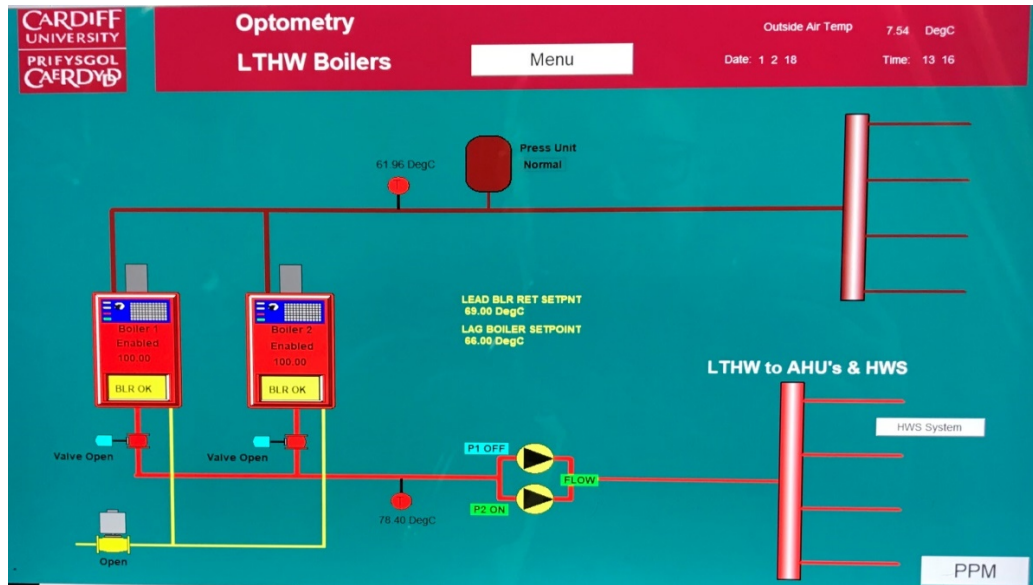


The Primary heating pumps have a set point of 350kpa with the Primary cooling pumps have a set point of 300kpa. The primary pumps have one pump set to standby.

The secondary heating pumps have a set point of 123kpa and the secondary cooling pumps have a set point of 170kpa. The secondary pumps do not have any pumps set to standby.

There are 2no Remeha Broag 210 Eco 160kW High Efficiency Condensing Gas boilers. The boilers show on the BMS dashboard schematic as providing hot water services and linked in to the Air Handling Unit.





There are 2no calorifiers used for hot water storage and a plate heat exchanger installed.



There is an issue with the Mapress pipe system installed throughout the building, which has resulted in numerous water leaks. A budget of £3.5 million has been set aside to replace this pipework in its entirety.

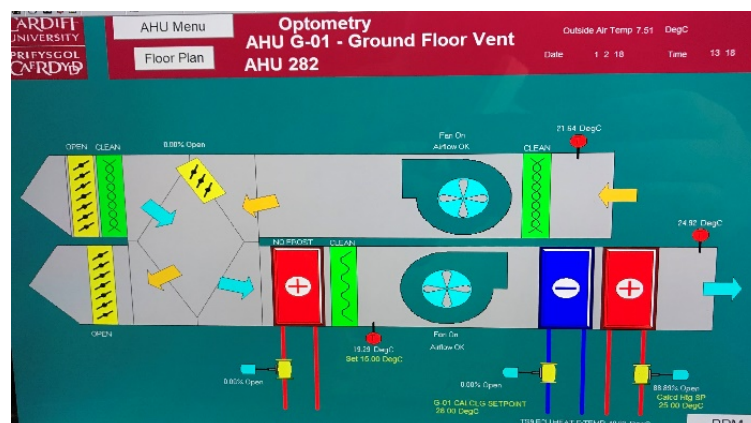
Within the second plant is a ClimaCIAT Concept air handling unit (AHU). The AHU connects to ductwork and distributes reconditioned filtered air from one part of a building to another.

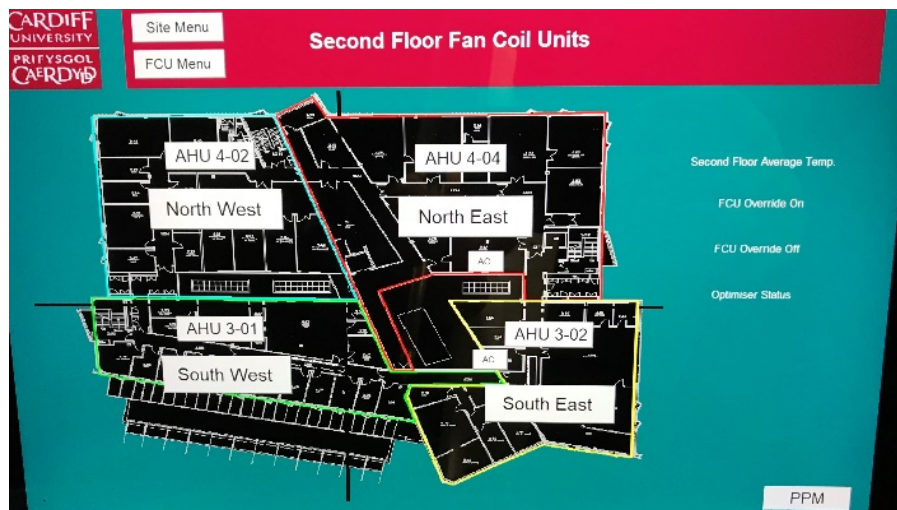


There are numerous Fan Coil Units (FCU) throughout the building which provide warm and cool air. These are thermostatically controlled and can operate in isolation or as part of a 'zone'. The AHU's and FCU are also connected into the BMS.



There is a Trend Building Management System (BMS) installed and Trend controllers linked into major plant equipment. The day to day operation and controls are managed internally, with BMS specialists being contracted in for more specialised works.





There are Passive Infrared (PIR) sensors in various locations that will operate the air handling unit for that specific location when occupancy is sensed. The system aims to put out temperatures of around 24 degrees centigrade and returns it at approx. 18 degrees centigrade.

There are 2no Grundfos Impress pressurisation units which are used to top up heating or chilled water systems.



The lighting scheme is a mixture of fluorescent, halogen and LED lighting, although LED fittings are in the minority. Currently lighting is only being upgraded to LED fittings when older light fittings fail.

Business Case – Maintenance Strategy

1. Purpose of Document

The purpose of this document is to undertake a review of the requirements for planned and reactive maintenance of the building engineering services for the Optometry & Vision Sciences Building, owned and managed by Cardiff University. Consideration should also be undertaken in relation to Cardiff University's other M&E equipment within their portfolio in the same geographical location.

2. Background and Reasons for the Project

2.1 Background

The Optometry & Vision Sciences Building was constructed in 2007, located in Cardiff and provides teaching facilities, eye clinics, laboratories and office space. The building provides services to the general public as well as academic and research facilities. It has modern M&E plant including Ground Source Heat pumps, gas fired boilers, air handling and fan coil units and dry coolers that are essential to the buildings general operation and usage.

The Energy Manager advised that the maintenance of M&E equipment is carried out by a combination of in-house and outsourced Service Providers. It was noted that Gas Servicing was undertaken by Gibson STS so it is assumed that the in-house team carry out minor maintenance and checks given complexity of other plant. The Building Management System (BMS) is also managed in-house with more specialist works being undertaken by a Contractor.

As a means of evaluation, a review of these processes has been undertaken to ensure work is satisfactory and value for money is being achieved.

2.2. Summary of Reasons for the project

- Undertake a review of the existing Maintenance strategy.
- Evaluate and implement new Maintenance delivery model.

3. Objectives

- Ensure ongoing compliance of all equipment to current legislative, Health & Safety, statutory and ACOP requirements.
- Increase efficiencies and effectiveness of the building services engineering maintenance service.
- Ensure existing Key Performance Indicators (KPI's) for reactive and planned maintenance are met.
- Reduce maintenance costs where possible, without detriment to the quality of service provided.

4. Scope

- A full review of the building service engineering requirements for the Optometry & Vision Sciences Building, Cardiff

5. Work Performed

The business case has been undertaken by reviewing:-

- Review of Industry Standard documents
 - o CIBSE Guide M
 - o BS EN 15341:2007 Maintenance – Maintenance Key Performance Indicators
 - o BSRIA BG 24/2012 Asset Management & Maintenance Audits
- Review of peer reviewed Journals on Maintenance Strategies

6. Benefits Summary

6.1. Potential Benefits of Outsourcing Maintenance Package

- Specialist engineers, knowledge of equipment, with greater labour resource.
- Flexible resource levels
- If outsourced to a national company wider parts stock network, often reduced cost of materials due to volume.
- Can gain competitive labour rates without risk of in-house salary creep, sickness, annual leave etc
- Contract can dictate financial penalties for lack of performance
- Better ability to monitor productivity

6.1.2 Potential risks of Outsourcing Maintenance Package

- Client may need to closely supervise work
- Greater administration burden on Client.
- Duration of contract remaining may dictate performance levels
- Dependant on the type of Contract used, costs may be difficult to control effectively.

6.2. Potential Benefits of In-House Maintenance Delivery

- Ability to react quicker to mechanical or electrical breakdowns
- Greater knowledge and familiarisation of Plant equipment and assets installed on site.
- Management may retain greater control of in-house maintenance regime, and quality standards.

- Better control of finances and expenditure.

6.2.1 Potential risks of In-House Maintenance Delivery

- Potential lack of resource during busy periods
- Supervision role required
- Difficult to adjust labour resource accordingly during quiet/busy periods
- Cost of training & developing staff
- Risk of losing staff following training process and loss of knowledge.
- Access to specialist tools and equipment

7. Option Evaluation

- Do Nothing – continue with existing mixed regime.
- Look to outsource all planned and reactive maintenance to Service Provider
- Bring all planned and reactive maintenance In-House.

Alexander (1996) identifies several drivers which organisations or companies may consider when looking to outsource maintenance services. With ever increasing advances in modern building technologies, an organisation may struggle to employ or retain engineers with the necessary skill sets to maintain a variety of plant. Additional risks are managing manpower shortages due to annual leave or sickness, which may make it unfeasible or economically viable to retain in-house.

Alexander and Young (1996) describe the process of outsourcing the servicing and maintenance to an external contractor as providing more assurances to the organisation that it is achieving market value, and reducing expenditure on in-house salaries and costs. Outsourcing may bring discipline to costs and prevent the in-house costs drifting above market level over time (Maechling & Bredeson, 2005).

Yik and Lai (2005) believe that specialist O&M contractors can deliver the service more efficiently due to a greater knowledge and skill set, and the ability to deploy this labour force more readily, allowing the organisation to focus on its core business. This knowledge can enable plant to run more efficiently saving an organisation financially.

There are other costs to consider though, in so much as the tender exercise itself and management of the contractor in ensuring servicing and maintenance are carried out to the agreed specification. Another risk is that an organisation may become wholly dependent on the contractor, and its knowledge of the site and equipment. Deterioration in performance and costs can occur when outsourcing and the focus should not be on short term advantages. (Alexander & Young, 1996; Jennings, 2002).

Without tight control and management of an outsourced contractor there is a possibility of premature failure of equipment if maintenance specifications are reduced without the client's knowledge to increase profits for the contractor (Redden 2007). This can lead to more critical failures, interruptions to services and reduced life cycle costings.

There is a danger that companies that outsource their maintenance may lose in-house staff with those skills and knowledge. If the outsourced contractor does not perform to the required standards these activities can no longer be carried out in-house without sufficient time to re-recruit. (Campbell, 1995). In-house staff may also take more ownership of their plant and assets. It's essential that any contractual responsibilities are clearly defined (Lai, Yik & Jones, 2004) to avoid disputes which may affect continuing performance.

If utilising an in-house DLO, an evaluation of resources, capabilities and the ability to manage peaks and troughs in workloads is key. If outsourcing, the type of contract will depend on maintenance budgets available and the scale of the portfolio. Once the legislative and statutory requirements are met an organisation needs to weigh up its next priorities in terms of levels of risk relating to building downtime, finance and employee and public satisfaction.

When deciding on a maintenance strategy careful consideration should be made to what procurement method or form of contract is decided on. There are many type of contract as detailed in CIBSE Guide M – Chapter 4 and an organisation will need to determine what is best fit for it. An organisation may favour a fully comprehensive contract or operate on Schedule of Rates. In the instance of outsourcing, several providers may be utilised owing to their specialism, and ability to be market competitive in that area rather than using a larger company that sub contracts to specialist sub-contractors.

Types of contract that may be used :-

- ICE NEC3: Term Service Contract (2005)
- JCT Measured Contract (2006)
- CIOB Facilities Management Contract (2008)

When considering both arguments for a wholly outsourced, or in-house maintenance service there are risks associated with both. Taking account of the specialist equipment within the building and if considering the Cardiff University's M&E assets in other stock, a sole in-house maintenance regime would appear to be unfeasible unless major investment in training and staff recruitment was undertaken. There is merit in retaining a smaller in-house team who can carry out basic maintenance tasks and checks, and provide a first response to breakdowns where possible to gather more information for the specialist contractor. This solution is also detailed by Tsang (2004).

Energy Audit Report

Optometry & Vision Sciences Building – Cardiff University



Andrew Richard Poole

Survey Date: 1st February 2018

Report Date: March 2018

ARP
Surveys

Audit

Optometry & Vision Sciences Building, Cardiff University Energy

Introduction

The purpose of an Energy Audit is to carry out an evaluation of the energy consumption of a building, site, or designated area. The audit will investigate and identify cost savings relating to energy consumption.

The Audit will provide proposals to reduce CO2 emissions, list the degree of ease, and cost effectiveness. It will promote effective control of energy usage for an organisation.

The audit will Benchmark results against benchmarks in CIBSE Energy Benchmarks TM46: 2008.

The Audit should form part of an overall Energy Management Plan for the organisation or owner. The methodology for the audit is in line with guidance from CIBSE Guide F and BIFM Energy Audits – Good Practice Guide.

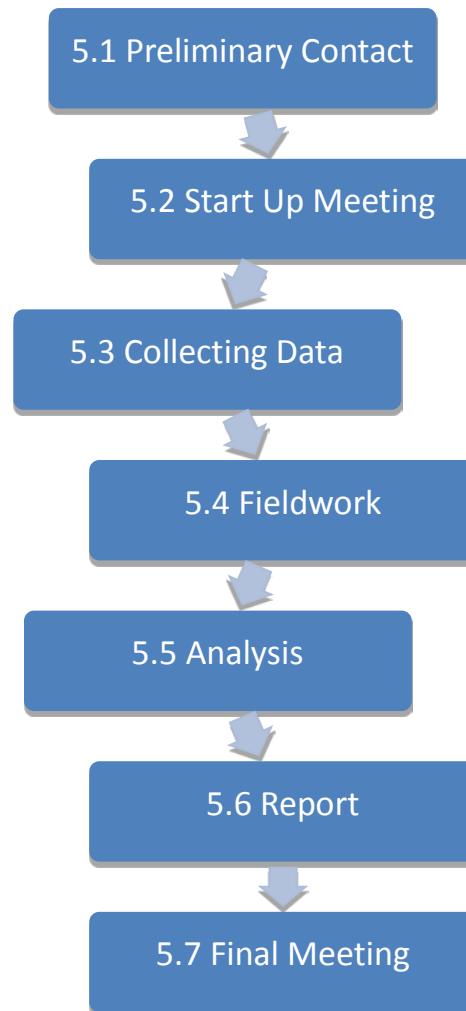
“Cost savings of over 60% have been achieved at sites where the potential had not previously been recognised. Such savings are usually obtained with payback periods of less than three years”¹

Limitations of Report

Areas accessed during the audit were limited so it was not possible to capture all equipment or plant installed. Energy data provided by the University had a number of estimated and missing readings due to a data breach in January.

¹ CIBSE Guide F *Energy Efficiency In Buildings* - Chartered Institute of Building Services Engineers

The audit process will follow the flow diagram as highlighted in BS EN 16247-2:2014 – BSI Energy Audits Part 2 – Buildings



1.0 Site Information

The School of Optometry & Vision Sciences Building is in Cathays, Cardiff near the City Centre. The front elevation of the building is in a traditional red-brick residential area, and to the rear backs onto an industrial estate. Constructed in 2007 at a cost of 21 million and has approx. 6300m² usable floor space.

The building is of modern construction and the external envelope is a mixture of terracotta wall tile finish and vertical sheet glazing. The building is open 8am – 8pm Monday to Friday generally. Whilst it is a University building it does not close during traditional University vacation periods, bar Bank Holidays. Staff and students may also use the building outside of these hours. The building provides specialist eye clinics, laboratories, research facilities, lecture theatres and office accommodation.

2.0 Current Energy Performance

Twelve months of energy data was provided by the University for the meters serving this building. Discrepancies and anomalies were found with some of these readings. Data in January was corrupt due to software issues and a breakdown in communications between the meters and BMS. A percentage of the readings provided were estimated from software installed for that purpose. Other meters appeared to reset to '0' for no apparent reason.

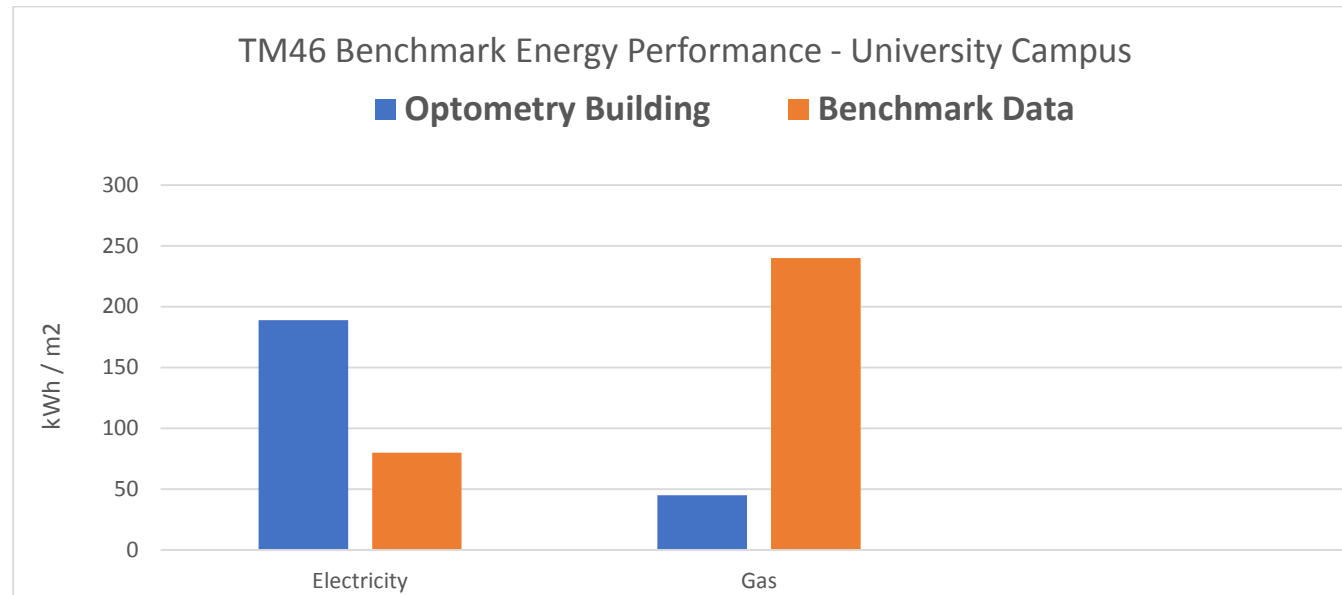
The table below details the energy consumption for the building. It is heavily weighted in electricity consumption, but the plant operating the main source of heating and cooling in the building runs on electric.

Energy Type	Consumption (kWh)	Carbon Output (tonnes)	Cost of Energy (£)	Price per kWh
Electric	1,424,027	136.67	142,402.80	£0.10
Gas	335,565	16.87	6711	£0.02

The above calculation was converted from kWh into kgCO₂e and then converted into tonnes²

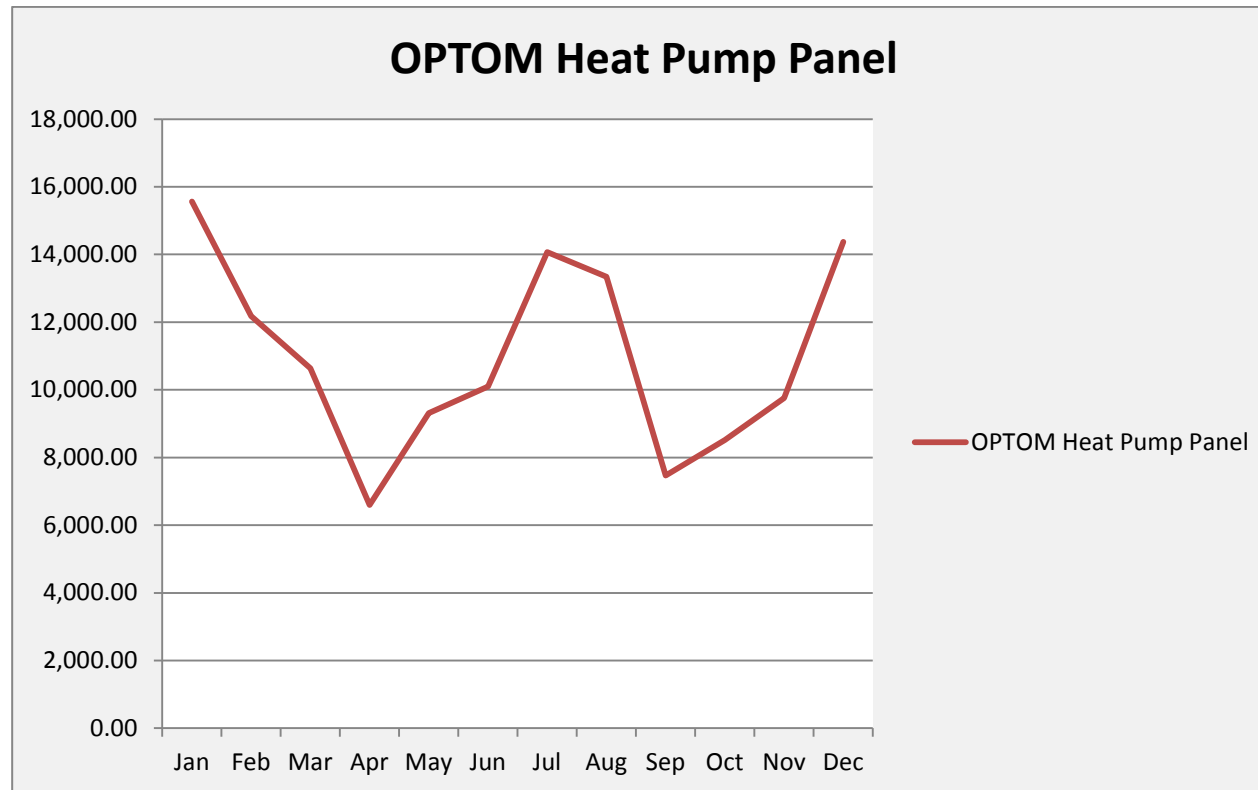
² - Carbon Calculator - <http://www.carbon-calculator.org.uk/>

2.1 Benchmark Energy Performance



The above graph shows that the Optometry building uses far more electric than the industry benchmark (Category 18 – University Campus). The calculation was worked out on a square meterage of 6297m² as identified within the Excel meter tree spreadsheet.

As detailed elsewhere in the report the reason for higher electric usage is that the GSHP's run on electric, and provide heating and cooling which accounts for the spikes in usage during both summer and winter. It is also worth noting that the Cardiff Optometry building uses far less gas than the Benchmark, given the gas boilers on site are only used for hot water services.



As the GSHP's have both a heating and cooling load, no degree day data graph has been provided within this report. The above consumption shows peaks during winter and in the summer months where cooling is required in the building.

3.0 Heating & Hot Water Services

The buildings primary source of heating is from 4no HydroCIAT Ground Source Heat Pumps that feed to underfloor heating, and fan coil units throughout the building. As detailed elsewhere within the report, the GSHP's are an efficient means of heating the building so there is little room for improvement currently.

“Ground Source Heat Pumps can make a big contribution to carbon savings in new buildings, with most teams predicting GSHP would provide carbon savings of 10%-20% compared with 2006 building regulations”³

Modern ground source heat pumps are also very efficient and can convert between 3-4kWh of heat from 1kWh of energy used.⁴

Hot water is provided from 2no Remeha Broag 210 Eco 160kW High Efficiency Condensing Gas boilers. Coupled with control from the Trend BMS these boilers should run efficiently for their purpose. During the At the time of inspection all pipework and valves observed had insulation or valve jackets installed which will conserve heat and thus save energy.

³ - <https://www.carbontrust.com/media/81349/ctg036-down-to-earth-ground-source-heat-pumps.pdf>

⁴ - http://www.gsnp.org.uk/Ground_Source_Heat_Pump.html

3.1.2 Controllers for Heating & Hot Water

The building has a Trend Controls Building Management System which allows temperature set points to be controlled in individual rooms or 'zones'. There are full time members of staff in-house who manage the day to day operation of this system. An investment of over £80k on hardware in the last financial year (Durdin, 2018) supports the view that the BMS is actively used by the organisation.

Energy Manager Mark Durdin (2018) advised that generally fan coil units set points are adjusted to 24 degrees centigrade with temperature returns coming back at around 18 degrees. If temperatures of each room taken as a blanket approach, some savings could be made by adjusting room temperatures which may not require this. An optimum start is programmed into the BMS to ensure the building is warm first thing in the morning when staff arrive.

Recommendations

There were faults identified on the BMS system relating to mis-readings or false temperatures. These should be resolved to ensure optimum efficiency.

4.0 Cooling & Ventilation

Cooling and ventilation is carried out by the GSHP's, moved by the air handling units and Grundfos pumps and distributed by fan coil units. Given the design of the building there will also be a limited amount of natural ventilation from openable windows. A previously carried Air Conditioning report⁵ has noted the presence of air conditioning units, but none were sighted during the audit inspection.

Recommendations

Rationalise time zones and all appropriate weekly time settings for areas. Reschedule all temperature setpoints.

⁵ HM Government Air Conditioning Inspection Report – carried out June 18th 2014

5.0 Building Envelope

For the purposes of this audit no As-Built information was provided as to the construction and insulation detail. At the time Planning Permission was granted, insulation levels would have been in accordance with Part L, of 2002 Building Regulations.

Large areas of the building envelope are glazed and may be subject to solar gains and affect visual and thermal comfort of occupiers. This in turn may affect the productivity of workers. Passive methods to prevent overheating in areas should always be considered above mechanical means such as over use of air-conditioning or fan coil units equipment.

There is a small element of solar shading to uppermost windows and glazing on the envelope of the building. Window film or blinds that do not unnecessarily restrict incoming daylight should also be considered where applicable elsewhere⁶.

Recommendations

Consider application of window film to reduce heat gain, visual discomfort, and reduction in use of FCU's or air conditioning units. Film technology need not affect the external or internal appearance of glazing.

A reduction of up to 21% in Heat Gain reduction and G-Value of 0.56 with 3M Prestige 70 Window film. Cost for supply and installation of £80.00 per m² from Applied Products Ltd, Swansea.

Other options detailed below.

Vista 90 - £30.00 per m²

3M silver 20 - £30.00 per m²

3M Amber 35 Low E - £45.00 per m²

⁶ National Energy Foundation Solar Shading Impact Report - http://www.nef.org.uk/themes/site_themes/agile_records/images/uploads/BBSA-NEF-Solar-Shading-Impact-Report-June-2016.pdf

6.0 Lighting

The lighting installed is a mixture of fluorescent tubes, compact fluorescent tubes, halogen bulbs and LED's. The lighting system is connected into the BMS, but is not fully optimised according to the Energy Manager. There is no programme or strategy currently in place to proactively replace older bulbs or fittings with a poorer energy rating, until they fail.

The Carbon Trust⁷ estimates that savings of up to 30% can be achieved by installing occupancy sensors, and a figure of 40% for photocell sensors. Research carried out by Von Neida, Maniccia and Tweed (2000) also confirmed the same.

In terms of controls most of the areas walked through appeared to be controlled from switches, with no occupancy sensors or photo sensors in areas with natural daylight.

Care should be taken to ensure the right type of bulb/fitting is installed with these controls. Compact fluorescent bulbs can take a while to achieve their brightest light output from being turned on, and may not be suitable for regular on/off switching.

Recommendations

If no Capital Budget becomes available to replace older fittings in a programme, then LED's (Light Emitting Diodes) should continue to be utilised to replace failed tubes or entire fittings as applicable. Priority should be given to replacing any T12, T8 or halogen bulbs as soon as practical given the difference in efficiencies.

As LED technology has improved resulting in projected 50,000hrs life expectancy, costs have also fallen meaning there are added benefits such as lower maintenance and lifecycle costs which can offset the difference in cost in purchasing. The savings are not so drastic compared to T5 lights but if replacing T5 fittings it may be prudent to consider replacing with LED fittings. LED's are better suited to running in conjunction with occupancy and photocell sensors.

⁷ Carbon Trust - <https://www.carbontrust.com/resources/guides/energy-efficiency/lighting/>

	Flourescent T8 Tube (5ft)	LED T8 Tube (5ft)
Power Consumption	58W	22W
Hours in use (per year)	Approx 10hrs per day, 5 days a week, 52 weeks per year = 2600hrs	
Kilowatt Hours per year (watts/1000*)	150.8 kWh	57.2 kWh
Cost per year per tube (10p per kWh)	15.08 kWh	5.72 kWh
Replacement Cost To Swap	£40 per fitting	
Payback	3-4 Years	
Lifecycle of Tube	10,000 hrs	50,000 hrs

	Standard Halogen Bulb (G10 etc)	LED Spotlight
Power Consumption	50W	5W
Hours in use (per year)	Approx 10hrs per day, 5 days a week, 52 weeks per year = 2600hrs	
Kilowatt Hours per year (watts/1000*)	130 kWh	13 kWh
Cost per year per tube (10p per kWh)	13 kWh	1.3 kWh
Replacement Cost To Swap	£3-8	
Payback	0-1 years	
Lifecycle of Tube	2-4000 hrs	50,000 hrs

Tables above show potential savings on a per fitting/bulb basis in converting over to LED technology

Photocell and PIR sensors can be utilised in areas to prevent lights being left on permanently. Energy savings ranging from 25-70% can be achieved depending on location, and sensors are relatively cheap achieving a payback in 0-2 years.

7.0 Water Savings

Water usage is possibly the last thought of utility when an Organisation looks to reduce energy and utility costs unless it uses water as part of its core business. A separate water audit could be considered to carry out a site survey, examine current bills and standing charges to ensure the right charges are being applied.

Recommendations

In the areas that were surveyed there was no evidence of any non-concussive/self-closing taps being installed in public bathrooms which could save up to 50% water usage at each outlet.

A 9litre WC Cistern fitted with a cistern volume adjuster could save up to £500 per year in water & sewerage costs⁸.

More modern cisterns converted to a dual flush valve mechanism can be retrofitted at around a cost of £20 to most cisterns. The payback on this would be around one year.

8.0 Behavioural Change

Behavioural change is key to ensuring energy usage is reduced in a large building. Individual departments should all take collective responsibility. There was some evidence in areas inspected of an attempt to change attitudes or behaviour to energy saving, but was not consistent, certainly in respect of light switches.



Behavioural changes can be 'quick wins' and cost relatively little to implement. These are detailed in the table 'Low Cost Measures'. Enrolling in a scheme such as the Green Dragon Environmental Standard award or similar may assist in promoting and offering goals to the Organisation.

⁸ Water Savings – www.envirowise.gov.uk/water

9.0 Consideration of Renewable Technologies

The buildings position is such that photovoltaics installed on the roof space could benefit from uninterrupted hours of sunshine with no buildings or trees overshadowing the roof space. A feasibility study could be undertaken to cost up and assess practicality of retrofitting.

10.0 Energy Saving Measures Identified

Low Cost Measures

Low Cost Measures	Cost	INFO	Low Cost Measures	Cost	INFO
Run 'Switch Off' Campaign for lighting/equipment	£100	Turning off photocopiers alone overnight and at weekends can save £42 and 183kg CO ₂ per year.	Ensure Cleaners do not leave lighting on when finished in areas not on sensors	£0	Training / tool box talks.
Do not use air conditioning with open doors/windows	£0	Training / staff awareness	Ensure windows cleaned to provide as much daylight as possible	£400	
Ensure BMS is monitored daily for failed sensors/plant	£0	In-house team monitoring. Ensure more proactive in replacing failed items	Set computers to go into standby mode when not in use for short/medium periods in daytime	£0	
Review building temperature set points with occupants/depts	£0		Monitor for any grant funding available for carbon saving measures	£0	
Install PIR or Photocell Sensors	£75 per area	Energy savings dependant on location installed. Detail in report	Review of fuel procurement and tariffs. Undertaken in house so no cost associated.	£0	

Medium Cost Measures

Medium Cost Measures	Cost	INFO	Medium Cost Measures	Cost	INFO
Installation of glazing film	£5,000	Reduction in heat gains, improvement in visual comfort	Carry out investigation into BMS faults and rectify	£800	
Carry out works to get lighting fully integrated onto BMS system	£2,500	Better controls, ability to save money.	Remove any older type light fittings/tubes for reduction in energy usage	£45	Approx £45 per fitting. Data will need to be collated on number

11.0 Conclusion

The building has fairly modern plant technology, although is lacking from any sort of renewable energy technology, which may be available from grant funding (REFIT Cymru etc). There appears to be significant investment in the BMS, but faults need to be rectified within reasonable time limits. The temperature set points should be reviewed within each zone or room as necessary as appear to be on high side. Start up or optimum start times should be under constant review to reflect occupancy in these zones also.

Lighting being fully integrated with the BMS, or at the very least being controlled more by sensors would also prevent unnecessary energy usage.

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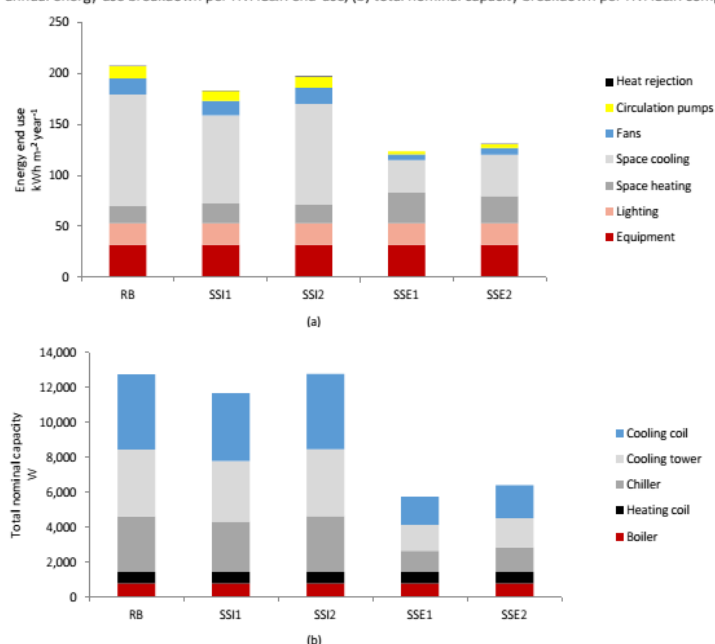
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APPENDIX

Appendix H: Energy modelling outputs per internal (SSI1) and external (SSE1) shade; internal (SSI2) and external (SSE2) blinds against a shading-free reference building (RB): (a) annual energy use breakdown per HVAC&R end-use, (b) total nominal capacity breakdown per HVAC&R component.



Source: National Energy Foundation – Data showing the benefits of internal or external shading on reducing energy loads from cooling.

Table 1. Industry estimates of potential energy savings for occupancy sensors (in %)

Space type	CEC	Esource	EPRI	Novitas	Watt Stopper
Private office	25-50	13-50	30	40-55	15-70
Open office	20-25	20-28	15	30-35	5-25
Classroom	-	40-46	20-35	30-40	10-75
Conference	45-65	22-65	35	45-65	20-65
Restroom	30-75	30-90	40	45-65	30-75
Warehouses	50-75	-	55	70-90	50-75
Storage	45-65	45-80	-	-	45-65

Source: Von Neida, Maniccia, and Tweed, 2000