

University Of Wales

Trinity Saint David

Msc Property and Facilities Management

Services & Energy Performance of Buildings

Building Services and Energy Audit



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1.0 **Introduction**

Cardiff School of Optometry & Vision Sciences, Cardiff University is four-storey University building that incorporates clinics, research labs and teaching facilities. Completed in 2008, the £21million project was the UK's biggest single investment in eye care.

This building is one of the more recent additions to the large portfolio already held and managed by Cardiff University majority of which are within a close proximity.

The building is serviced by some technologies that would have been considered as innovative for their time, such as a ground source heat pump system.

The building would have been designed and constructed in line with L2, Conservation of fuel and Power of the Building Regulations and in doing so would be considered as energy efficient.

This report will examine the main items of Building Services Equipment, consider appropriate maintenance strategies and audit the energy consumption of the building.

2.0 The Mechanical Engineering Systems of Cardiff University School Of Optometry And Vision Sciences.

- 2.1 **Ground Source Heat Pumps** – The Building has a complex heating and cooling system fuelled by ground source, 56 boreholes 100m deep, house heat collecting pipes in a closed loop, these pipes containing fluid, extract stored energy (heat) from the ground at low temperatures. This fluid is then passed through four HYDRACIAT – DYNACIAT LG LGP 500v 3X400V and pumped through to the underfloor heating on the ground floor, fan coil units or an air handling unit, and provides heating and air conditioning to the building using a set of valves located on a hydraulic system.

Ground source heat pump systems are very efficient, every kilowatt of electricity consumed to run the pump, can generate three to four kilowatts of heat for building. How efficient a system is depends on the quality of the design, and the standard of the installation, over engineered systems can result in the system being less efficient.

(Ground Source Heat Pump Association, 2018)



Fig.1

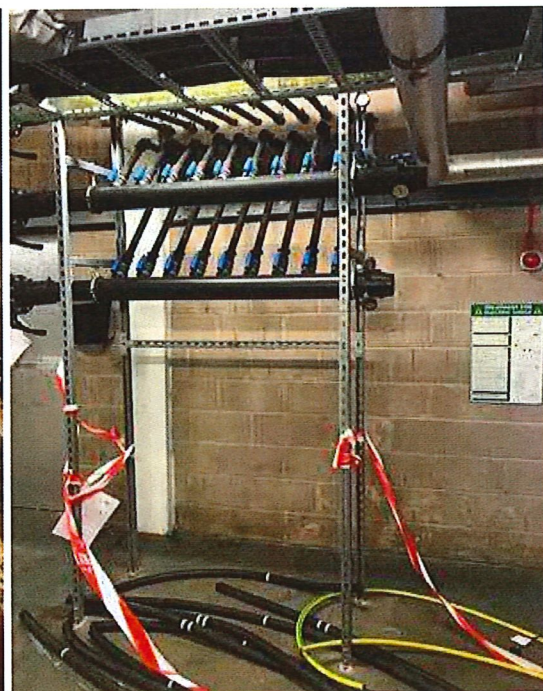


Fig.2

There are six Grundfos pumps that are used to pump the hot and cold fluid around the building to the fan coil units

2.2 **Air Handling Unit** – ClimaCIAT concept Air handling unit used to supply and circulate air around the building, it also extracts stale air as part of a building's heating, ventilating and air conditioning system. Supply air is passed through the AHU, it is filtered and is either heated or cooled to temperatures dependant on set parameters and the ambient weather conditions. In some buildings, Air Handling Units are used only to supply fresh air for ventilation and extract stale air.

AHUs are connected to central plant such as boilers, chillers or in this case heat pump, they receive hot or chilled water for heat exchange with the incoming air.

Heating or cooling may also be provided by electric powered heating elements or direct expansion refrigeration units within air handler.

When Air Handling Unit is used to remove stale air from the building, a controlled amount can recycled into the building to reduce the amount of conditioned air supplied.

Air Handling Unit can also incorporate heat recovery mechanisms; this allows warm air to be extracted from being expelled and use it to heat the incoming air supply.

(SAV System, 2018)

Fig.3



2.3 **Fan Coil Units** - Fan coils units are used to distribute heat and cooling within or close to the area being served. Electrically powered fan units are used circulate the room with air.

Historically, forward-bladed centrifugal fans in fan coil units have been driven by AC (alternating current) motors that run at constant speed. More modern fan coil units are driven by EC (electronically commutated) motors. These motors are more efficient as they can operate in variable air volume mode. AC motors are typically considered to be around 45% efficient and EC motors are 80% efficient.

(CIBSE, 2012)



Fig.4

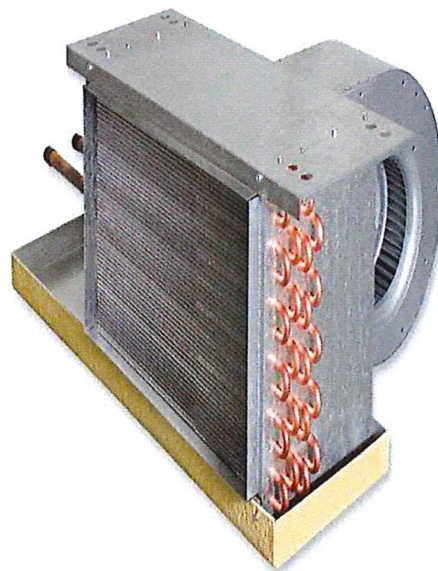


Fig.5

- 2.4 **Gas Boilers** – There are two mains gas fuelled free standing High efficiency condensing Remeha GAS 210 Eco boilers. These boilers are approximately 95% efficient. And are used in conjunction with a plate heat exchanger to provide hot water to the building.



Fig. 6

- 2.5 **Lighting Systems** – Lighting is provided by a mixture mains power of T5 and T8 fluorescent lamps and LEDs. These are controlled locally by manual switches, the building management system has the ability to control the lighting but either the connection hasn't been made or the parameters have been set incorrectly. There don't appear to be any photoelectric sensors or PIR Sensors

Fig. 7



Fig. 8

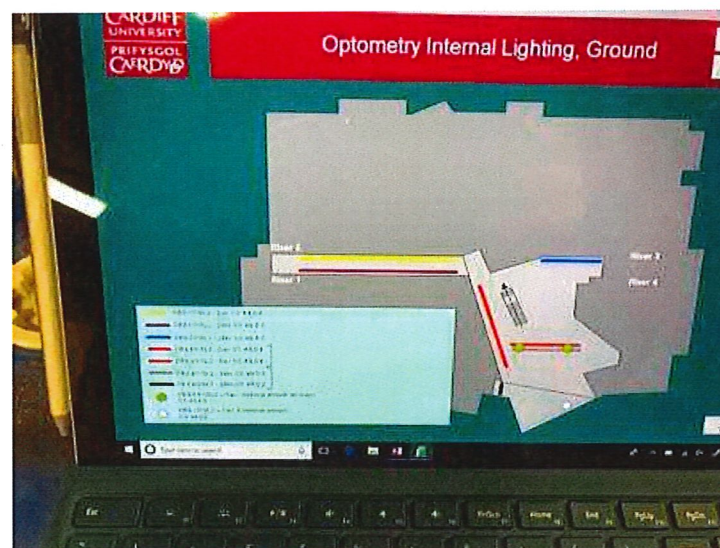
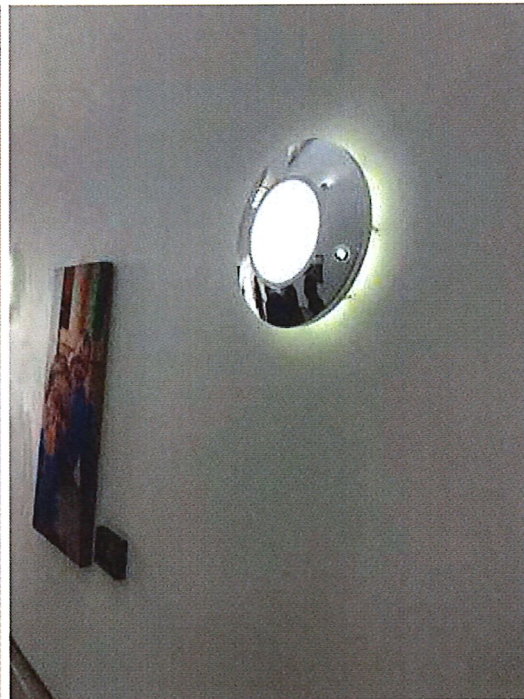


Fig.9

2.6 **Building Management System** – there is a Trend BMS that is used monitor and control energy services such as lighting, heating, ventilation and air-conditioning, ensuring the building operates at maximum levels of efficiency and removing wasted energy usage and associated costs. To achieve the optimal efficiency levels the system needs to be continuously maintained to achieve the correct balance between operating parameters, environmental conditions, and energy usage.



Fig. 10

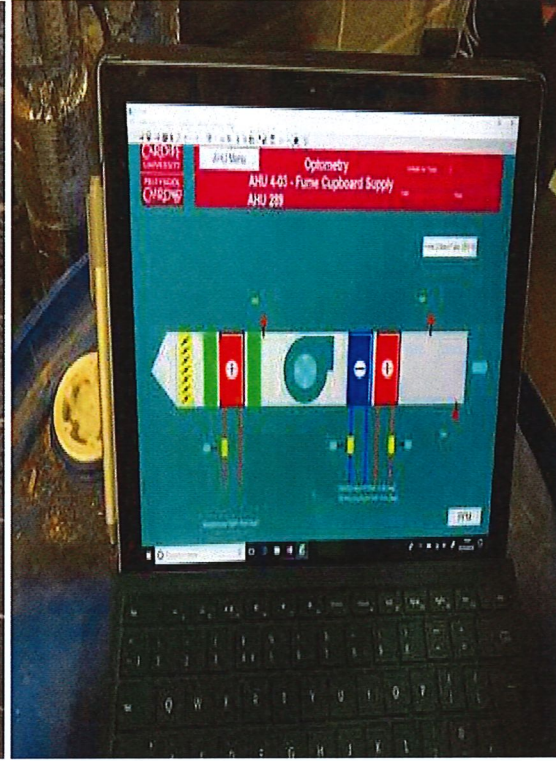


Fig. 11

2.7 Hot Water System Schematic Diagram

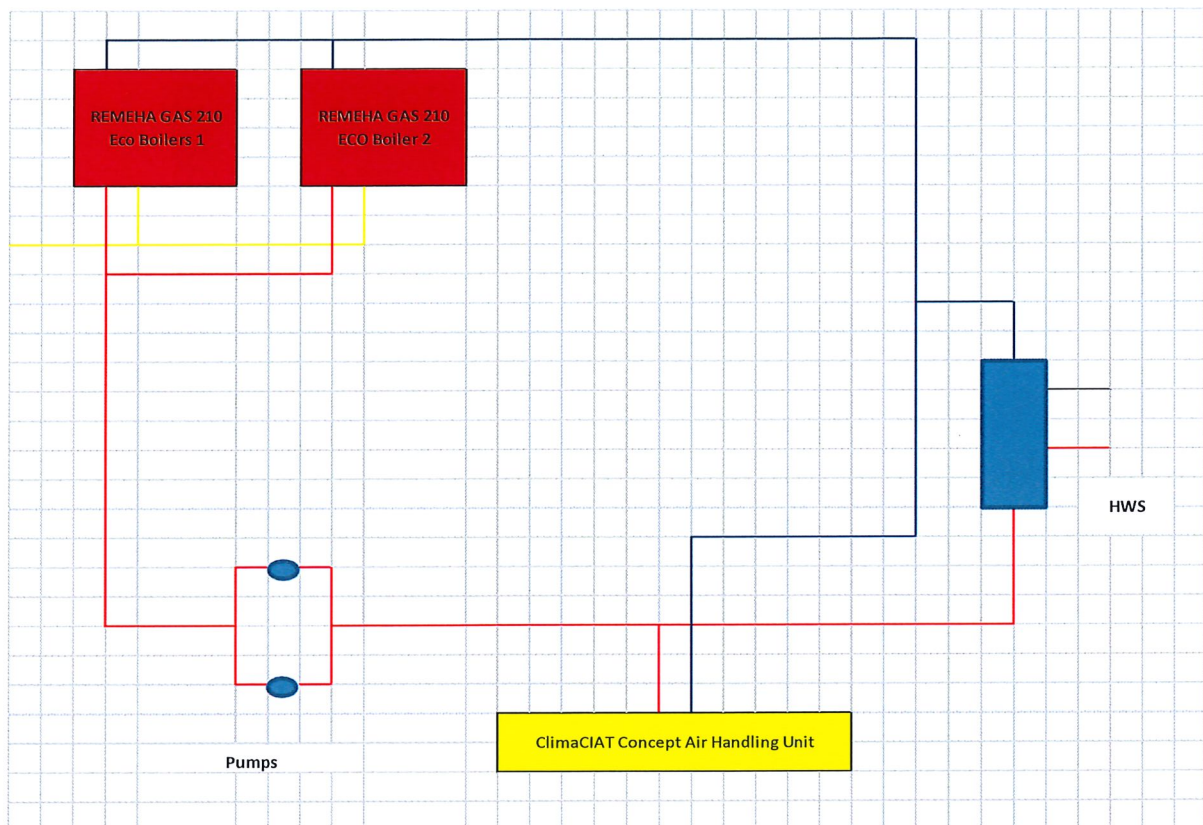


Fig. 12

2.8 Space Heating and Cooling Schematic Diagram

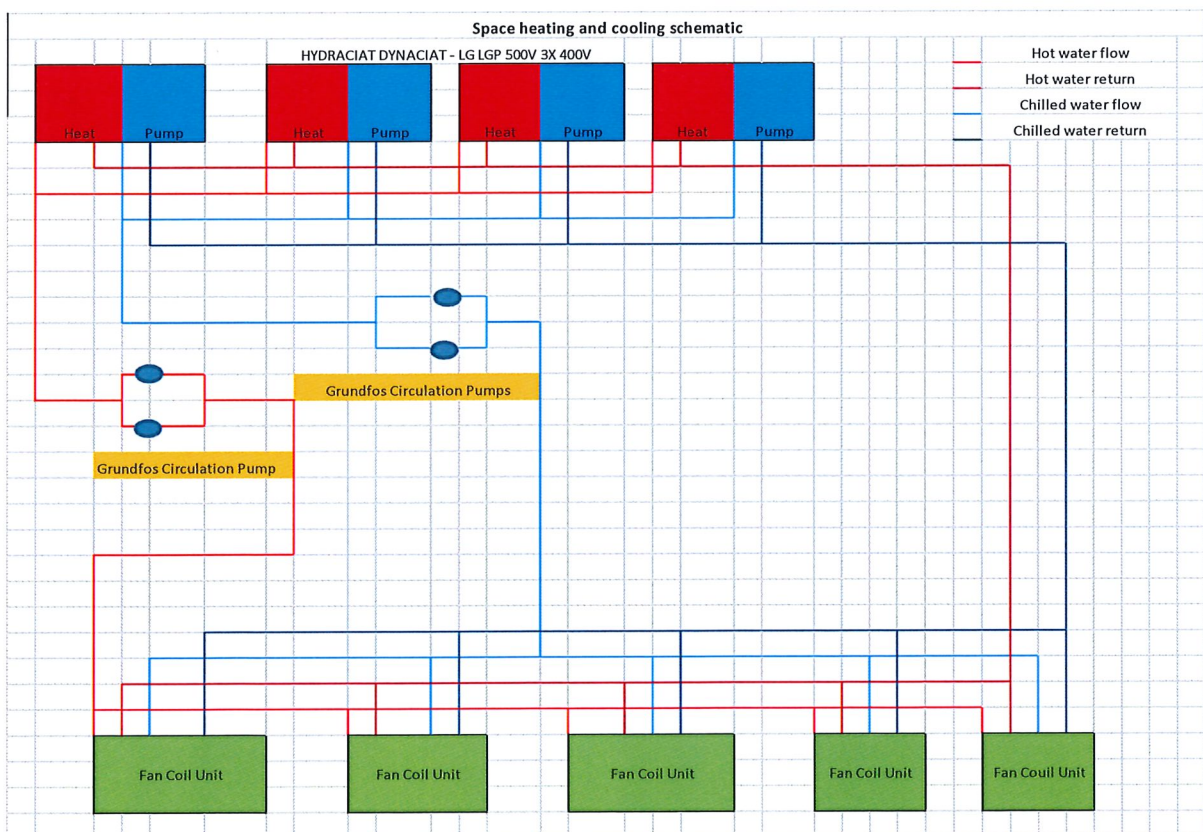


Fig.13

3.0 **Maintenance Strategy for Building Engineering Systems at Cardiff University School Of Optometry And Vision Sciences.**

- 3.1 The engineering services within a building play a significant role in how an organisation meet its corporate and social objectives, this includes providing an efficient, comfortable, safe and as far as reasonably possible environmentally friendly building.

Therefore how a building is operated and maintained requires strategic approach in order to meet these objectives.

The maintenance strategy will need to clearly define the different types of maintenance (reactive, planned, and preventative) required for each element of plant and how they are dealt with, this will be governed by statutory legislation, health and safety legislation, approved code of practice, manufacturers guidance, advisory literature as well as regimes set out in site based risk assessment and occupancy requirement.

- 3.2 **Re-Active or Unplanned maintenance** – This is when maintenance is carried out to solve a problem, or after a fault has been recognised, and used to restore the equipment to a state in which it can function as required. By employing just this method of maintenance equipment / Assets may deteriorate quicker than expected. In newer assets it may void manufacturers warranty.
- 3.3 **Run to Failure maintenance** - is where the consequences are reviewed and found that the asset can be utilised safely and efficiently without serious loss of service and risk of failing to meet statutory requirements and balanced against the cost and resource required to replace rather than maintain. Run to fail implies that an organisation will expect inevitable failures and will have sufficient parts and qualified staff on hand to ensure the downtime is kept to a minimum. The allowable downtime is calculated on a case by case basis.
(Multitrade, 2008)
- 3.4 **Planned & Preventative** – This is when maintenance is carried out in an organised manner and follows a prescribed maintenance schedule. This

schedule identifies the intervals suggested to ensure the probability of failure or reduction in the life cycle is kept to a minimum.

- 3.5 **Statutory inspections** - are carried out at planned intervals to assess condition and ensure health and safety compliance, the frequency of such inspections are set by risk assessments or documented in legislation. Failure to carry out this type of servicing and holding sufficient records can lead to prosecution by the HSE.

To help standardise frequencies within the industry the Building Engineering Services Association collate and maintain a growing library, SFG 20, that provides maintenance task schedules that cover all principal types of heating, cooling and ventilation, installation and plant, and electrical services complete with technical updates and legislative references.

(SFG 20, 2018)

- 3.6 **Condition based maintenance** - is also carried out in a planned manner; tasks are carried out to equipment that have been monitored and found to be having reduced performance levels. This type of maintenance is particularly prevalent where equipment is

- Expensive to maintain
- Expensive to replace if run to failure
- Difficult to access for maintenance
- High costs relating to failure
- Critical to a buildings operation

- 3.6 **Delivering the Service** – When considering the case study building of Cardiff University School of Optometry And Vision Sciences there are three principal options available to deliver the service.

- Direct Employed Labour
- Outsourced to a service provider
- A combination of both (let to individual sub contractors but managed internally)

A comprehensive business case should be developed to ensure a considered approach is utilised.

4.0 **A Business Case to Consider the Approaches to Maintenance of Building Engineering Systems at Cardiff University School Of Optometry And Vision Sciences.**

4.1 **Overview**

Cardiff School of Optometry & Vision Sciences, Cardiff University was built in 2008 and is four-storey University building that incorporates clinics, research labs and teaching facilities. The University hold a portfolio of similar buildings across Cardiff. The university has a Direct Labour Organisation actively working across Cardiff.

The purpose of this business case is to identify the preferred option for the maintenance of Building Engineering Systems.

The building engineering systems servicing the building are considered complex and of a commercial nature, they require they the following types of maintenance

- Re-Active or Unplanned maintenance
- Planned & Preventative
- Statutory inspections.

4.2 **Options**

In this setting there are three options to consider

- Utilisation of Direct Labour
- Outsourced Service
- Hybrid – Part outsourced, part resourced directly

4.2.1 **Direct Labour** – This option utilises the services of in house work force to carry out all the maintenance needs of the building. There are advantages and disadvantages such as

- Control & Flexibility work force
- Reduction In Opportunism
- Loyal workforce
- Unable to compete financially with outsourcing
- Increased labour costs

Smith, 2012, has the view that not all maintenance can be performed by in-house maintenance teams. With some engineering systems, the lack of skilled in-house staff or because the asset requires specialised equipment for proper care, can lead to needing being outsourced.

(Smith, 2012)

4.2.2 Outsourcing - Outsourcing is defined as the procurement of services from sources that are external to the organisation. By following a tender process where a service is specified the following advantages and disadvantages are apparent

Outsourcing can be used to gain specialised expertise which organisations cannot justify developing in-house. Whilst outsourcing can prove cost effective, it should also be an integral part of the overall strategy that allows an organisation to concentrate on core functions.

(Hammad et al, 2010)

Hammad et al 2010 also states "By outsourcing, a higher level of expertise can be obtained at a lower cost. Outside experts can not only help in re-engineering processes to make them more efficient, but they can also apply the most useful new technology and ultimately raise flexibility and productivity to reduce the overall costs."

There are disadvantages such as Contract set up costs, monitoring costs, possible security breaches, loss of internal facility knowledge

(Alexander, 1996) (Graham, 1996)

4.2.3 Hybrid – Part outsourced, part resourced directly – This is where day to day maintenance, testing and inspection of non-specialist "core" equipment such as lighting and small power is carried out by suitably qualified maintenance team, all specialist maintenance tasks are precisely specified, tendered and performance evaluated. This ensures the equipment is maintained efficiently by specialists who keep pace with rapidly changing technologies; continue to develop specialist skills of their workforce; and readily have access to specialist equipment required to maintain certain systems. (Hammad et al, 2010)

4.2.4 Conclusion & Recommendation

Hybrid - Giving consideration to the information available and realising the size of Cardiff University's estate, I consider the best course of action to be keeping the core maintenance activities such as basic plumbing and electrical fault finding, and repair, serviced by the university estates team, this will allow a certain amount of control over how the building is maintained . Specialist servicing and maintenance of Ground sourced heat pumps, Air handling units and associated plant should be clearly specified by a suitably qualified M & E consultant and procured through a tender process considering both cost and quality. Such contract should consider timescales for repairs and penalties for service failure.

5.0 **An Energy Audit of Cardiff University School Of Optometry And Vision Sciences, Maindy Road, CARDIFF, CF24 4HQ.**

5.1 **What is an Energy Audit?**

An energy audit is an evaluation of energy consumption of a building or process that can be used to determine ways in which energy can be conserved. It is a process used to reduce the amount of energy input into the system without negatively affecting the output.

5.2 **Site Description**

Cardiff School of Optometry & Vision Sciences, Cardiff University is four-storey University building that incorporates clinics, research labs and teaching facilities. The building has a floor area of 7,523m² and was constructed in 2008.

The four storey building is of steel frame construction, with insulated panels and large areas of glazed curtain walling, it is heated by a ground source heat pump system, there is underfloor heating on the ground floor and fan coil arrangement on the upper floors servicing both heating ventilation.

The main entrance door leads directly in to a large glazed atrium, this encompasses the four floors, offices, laboratories, and teaching space and lecture theatres are access from an open gallery landing that lead on to other corridors. The building has been designed and decorated to allow as much natural light in as possible and make the most of it once it's in.

There are a number of plant rooms in the basement area that house the majority of the Mechanical and electrical services.

These include Ground Source Heat Pumps, Air Handling Unit, BMS unit, Gas boilers, calorifiers and plate heat exchangers for hot water, inverter driven pumps, and main electrical intake and distribution boards.

The Ground floor is heated by underfloor heating and the upper floors are heated and cooled by fan coil unit.

A Display Energy Certificate report has been made available, however the validity of this report is in question as it shows an operational rating of F(140) with the typical being 100. The advisory report failed to highlight any recommendations.

The site's usual opening hours are:

- Monday-Friday: 08:00 – 22:00
- Saturday and Sunday: 08:00 - 17:00

5.3 Current Usage

The table below shows the annual energy usage, cost and carbon emissions taken from data supplied by the university for a twelve month period. This data has been used to calculate the carbon footprint of the site in relation to its energy usage. Whilst the information provided appears to be comprehensive many of the meter readings have been calculated by the system and may prove to be inaccurate.

Utility Type	Consumption (Kwh)	CO2e Emissions (tonnes)	Cost (£)	Pence/ Kwh
Gas	267646	49	£5352.96	2
Electricity	1424028	753	£142,402.80	10

5.4 Bench Marking

There many ways to assess the energy performance of a building.

Benchmarking is an accepted method; the subject building is benchmarked with similar buildings.

Guidance documents Such as CIBSE Guide F and CIBSE TM 46 both provide benchmarking data for typical and good practice based on a per square meter approach for buildings categorised as being similar.

For this Audit the benchmarking data was gathered from CIBSE TM 46.

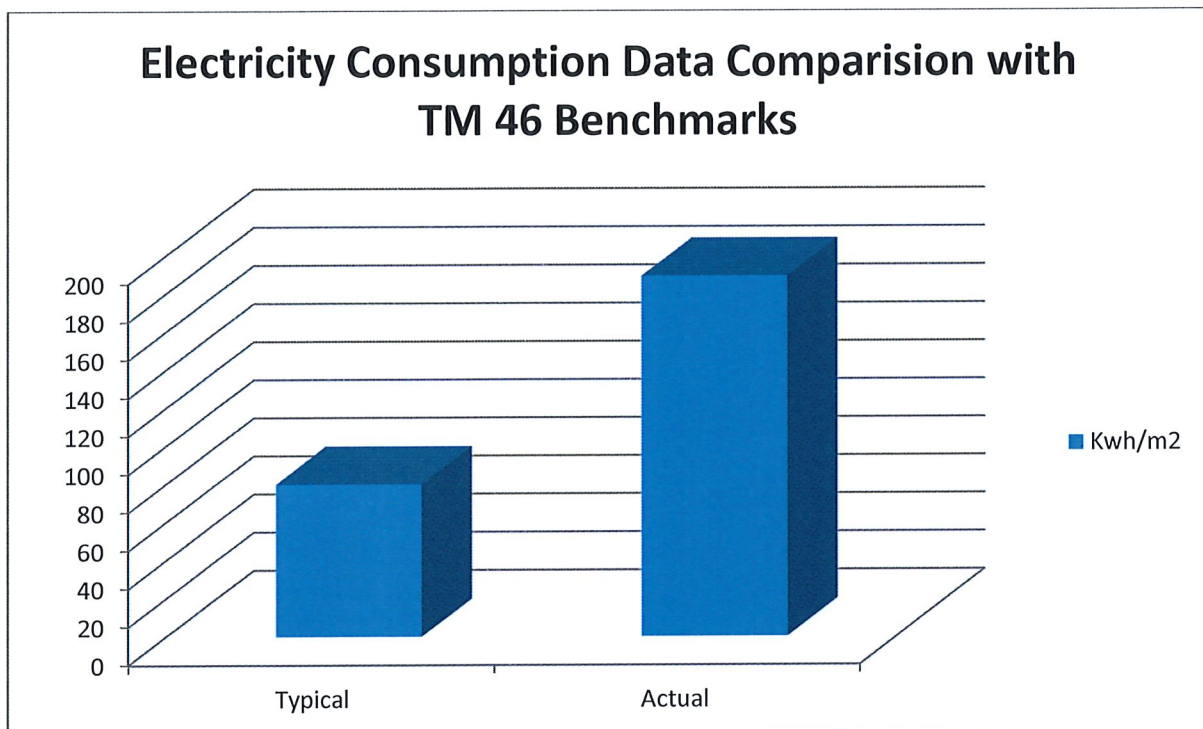


Fig. 14

By benchmarking it can be seen that the University building is 136% less efficient than a typical building. However, this data should not be analysed in isolation.

The building has an electrical consumption far in excess of which could be considered good practice; this is due to its ground source het pump consuming more electrical power, due to fans etc.

This then artificially improves the gas benchmark result.

The electrical supply to the HVAC equipment is individually metred, however the data supplied could not be relied on.

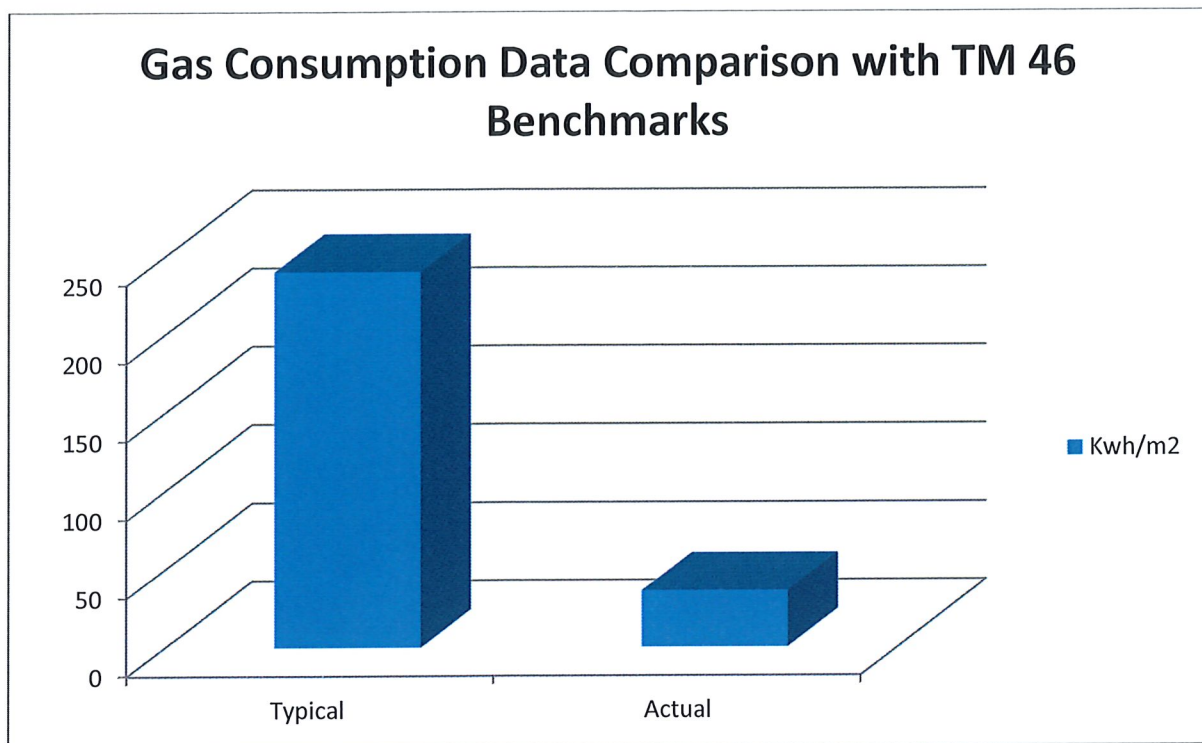


Fig. 15

Figure 13 shows the Actual gas consumption benchmarked against typical data for a similar building as published in CIBSE TM 46. This shows the building is 84% more efficient than a similar typical building. As previously stated this data shouldn't be considered in Isolation as the gas is only used to provide hot water to the building.

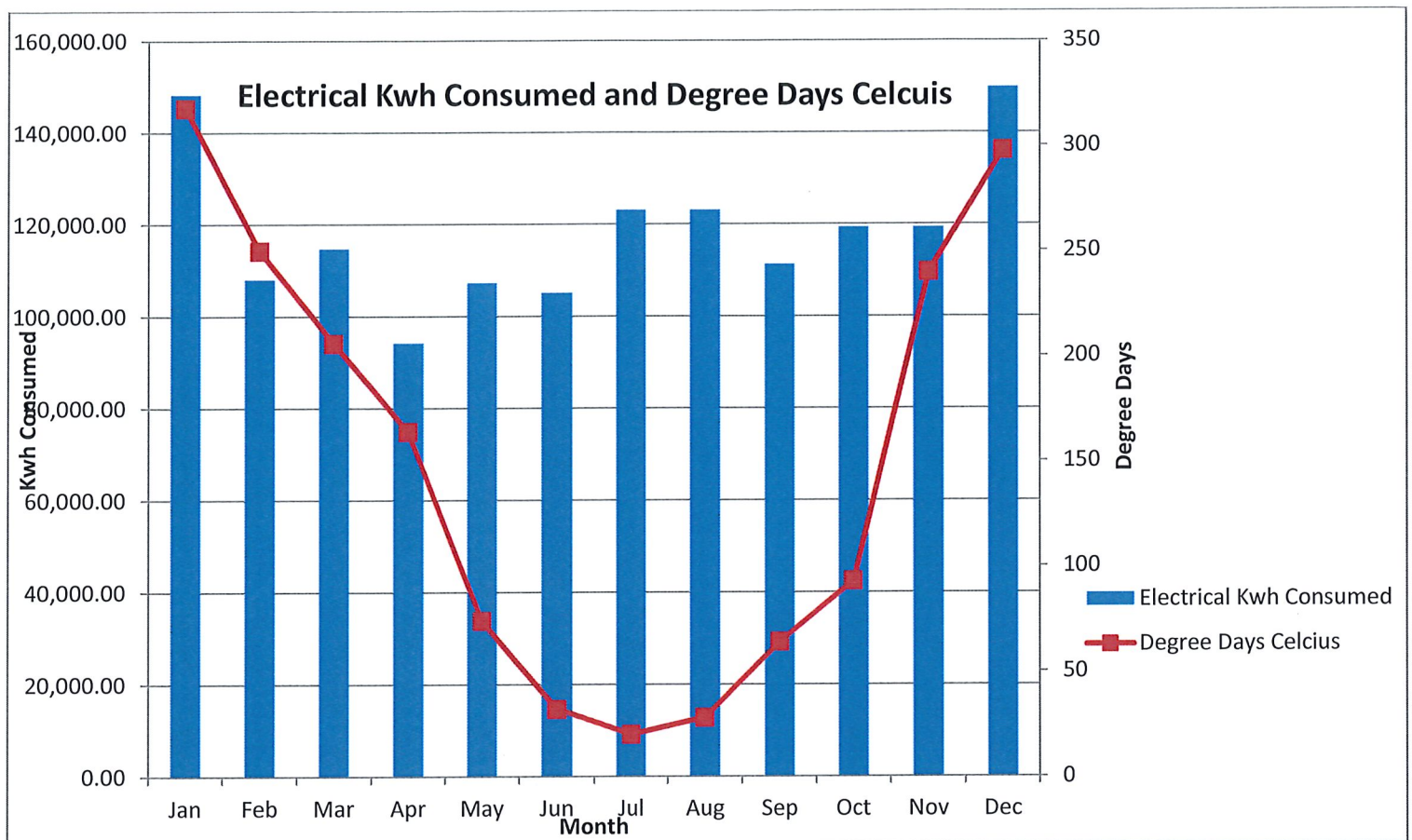


Fig. 16

Degree Days

Degree days data can also be used to analyse the energy performance of a building, by plotting the degree day data against the energy consumption of the heating system over a period of time (In this case January 2017- January 2018)

Where a building is equipped with heating and cooling it is possible to identify possible conflicts in the control system, such that there may be simultaneous heating and cooling or overlap in the system operation.

(CIBSE, 2006)

Figure 14 shows the monthly electrical consumption against monthly heating degree days. Whilst this example does highlight a trend it is not as evident as if it was considered for a gas heating system. The HVAC system relies on electricity to both heat and cool the building. As previously stated, the supply to the HVAC kit has been individually metered, but the data has been estimated.

5.5 **Opportunities & Recommendations**

5.5.1 Lighting

LED Replacement

It was noted that the majority of the lights in the within the building were either T5 or T8 Fittings, some LED replacement have been fitted, but this appears to have been carried out as an individual repair/replacement.

Morgan Pattison et Al, state that there has been a *“monumental shift from conventional lighting technologies (incandescent, fluorescent, high intensity discharge) to LED lighting”*. The primary reasons cited for this are energy efficiency and associated cost savings. *“LED lighting is now more efficacious than any of the conventional lighting technologies with room to still improve”*.

Although the initial financial outlay for LED bulbs will be higher than direct Replacement, LED lights are often more than 10 times more efficient than traditional lighting of similar output.

There are further advantages LED such as:-

- Long bulb life (meaning reduced maintenance costs).
- Low heat emission (meaning safer handling of lights).
- RGB LED fixtures are available which produce a variety of colours (to add more control for parties and other users) if required.

Lighting Controls

The lighting system within the building appears to be manually controlled. The BMS system has the ability to control the lighting levels within communal areas, however this appears either not to be linked or parameters incorrectly set. Other area such as teaching space, laboratories and welfare facilities the installation of occupancy sensors should be considered.

Littlefair, (2001) highlights that occupancy sensor can lead to large energy savings in occupied areas. By using presence detectors, such as PIR (passive infrared) savings of 10% to 19% have been reported for classrooms (Floyd, et al., 1995; Rundquist, 1996), and of 27% to 43% in private offices (Jennings et al., 1999; Maniccia et al., 1999; Seattle City Light, 1992). VonNeida et al (2000)

Consideration should also be given to installing Photoelectric switching, Littlefriar, 2001 suggests "*Photoelectric switching has the potential to save energy by turning off lighting when daylight illuminances are adequate*". However, he also raises issues with this type of control as it can be unsettling for occupants as it takes away the control from the occupant.

5.5.2 HVAC

Heating: Substantial savings can be made by ensuring buildings heating systems are working efficiently, and maintained correctly substantial savings can be made.

By ensure the buildings temperature is controlled correctly and perhaps lowering the temperature by 1 degree you can save up to 8% of your annual bill. Regular maintenance and replacement of inefficient equipment will help contribute to savings.

(Thorpe, 2014)

It was noted that supply and discharge vents in the basement plant room where positioned close together; this will lead to the system working harder and a possible short circuit.

5.5.3 Building Management Systems

Building Energy Management Systems monitor and control services such as heating, ventilation and air-conditioning, ensuring the building operates at maximum levels of efficiency and removing wasted energy usage and associated costs.

This is achieved by continuously maintaining the correct balance between operating requirements, external and internal environmental conditions, and energy usage. By carrying out a basic review of the schematic software whilst on site, there appear to be a number of discrepancies. A full review of the system controls should be carried out to check set parameters and investigate the possibility of faulty sensors

The Trend Control system running the equipment at this university building claim "*A BEMS can efficiently control as much as 84% of your building's energy consumption*" (Trend, 2018)

Katipamula, 2005, states improperly controlled equipment wastes an estimated 15% to 30% of energy used in commercial buildings. This further endorses the obvious savings that could be made by having a system overview and programme replacement of faulty control equipment.

5.5.4 Engagement Strategy

Many studies have found that individual behaviour changes can produce significant energy reductions, ranging from 5% to 50%. These savings can be achieved by developing a suitable behaviour change campaign.



Fig. 17



Fig.18

Whilst there were dated examples of good practice displayed through the building, there is justification to look at implementing the following procedures

- Start an awareness campaign
- Strategically place posters and stickers to aid staff make the correct decisions
- Provide Information through group emails
- Investment into promotional material
- Publicise externally the good work being carried out
- Appoint Energy Champions to help promote the cause – possibly incentivise departments for greatest savings
- Energy Competitions
- Engage with staff for their opinions and promote suggestions scheme

This type of engagement strategy is relatively cost effective and can reap rewards.

(Carbon Trust, 2013) (Thorpe, 2014)

5.5.5 Other Building Components

Passenger Lift – The lift motor room was not made available during the audit however passenger lifts are known to consume between 3% and 5 % of the overall consumption of a building, some of the following need to be considered for implementation in order to reductions.

- Select a best traffic control strategy.
- Omit parking feature.
- Initiate/install controller standby after idle period.
- Turn off car lights when on standby
- Ensure regular preventative maintenance.
- Set acceleration/deceleration to lowest acceptable values.
- Set levelling/creep distance to be small.
- Ensure guide rails are adequately lubricated.
- Select the lowest possible values for acceleration/deceleration/jerk
- Ensure the Ensure the car top and lift well lights are switched off when not in use.

(Barney, 2007) (ISR-UC, 2010)

Draught Lobby

The main entrance doors open directly into the main atrium, heat is lost when doors are opened to the outside. Consideration should be given to constructing a draught lobby; there should be sufficient space for the outer door to be closed before opening the inner door, a draught lobby operates in a similar fashion to an air lock.

In order to be considered as a draught lobby, the space should be a minimum of 2m² in floor area, it should open circulation space, and should have sufficient space so the a person with a push-chair / wheelchair is able to close the outer door before opening the inner. The lobby dimensions should be a minimum of 1.2m deep by 1.2m wide.

(NEP Energy Services, 2018)

Water Saving Measures

Whilst the building data does not provide any information on water usage, it was noted whilst on site that there are opportunities to make savings. Simple measure such as fitting PIR sensors to Urinals/WC flushes, cistern displacement devices, fitting tap aerators, and fitting self closing taps can all reduce the amount of water wasted at the site.

Photovoltaic Energy

As the building relies heavily on Electric power to service it HVAC system, consideration should be given to installing Photovoltaic panels to help reduce mains usage.

6.0 Recommendation Pay Backs

Recommendations with Pay back within 3 Years

Recommendation	Potential Impact
Replace existing fittings with LEDs	Medium
Improve Lighting Controls	Medium
Review BMS Controls	Medium
Implement Engagement Strategy	Low/Medium
Install water saving measures	Low
Review Lift Strategy	Low Medium

Recommendations with Longer Pay back periods More than 7 years

Recommendation	Potential Impact
Install Draught Lobby	Medium
Installing Photovoltaic Panel	High

7.0 **Conclusion**

The information researched in this report outlines that by understanding how different types Buildings Services Equipment operate, the types of maintenance and statutory compliance inspection required and having an informed maintenance strategy can increase equipment life cycles and ensure efficient use of the buildings services.

By carrying out energy audits, we can demonstrate how continuous review of services and consumption can identify and suggest opportunities to reduce carbon emissions and make cost savings. This review can highlight failures in existing services and building fabric as well as suggesting new technologies that can improve efficiencies in a retro fit situation.

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Fig.4	Fan Coil Vent
Fig. 5	Fan Coil Unit
Fig. 6	Gas Boiler (LTHW)
Fig. 7	Lighting Example
Fig. 8	Lighting Example
Fig. 9	BMS Front End Screen showing ability to control lighting
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