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RESULT

MASTER'S DEGREE ASSIGNMENT SPECIFICATION

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Hand Out Date:	13 May 2021	Submission deadline:	24 June 2021

Referencing:	In the main body of your submission you must give credit to authors on whose research your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have read or quoted in order to complete this assignment (e.g. for books: surname of author and <u>initials</u> , <u>year</u> of publication, <u>title of book</u> , edition, publisher; place of publication).			
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Learning Outcomes tested (from module syllabus)	Assessment Criteria: To achieve each outcome a student must demonstrate the ability to:
1. Systematically <u>understand the</u> issues involved in operationally managing building engineering services (<u>BIFM Competence 10 – Managing building services</u>).	Address Tasks One and Three
2. Critically analyse building engineering services maintenance strategies (<u>BIFM Competence 10 – Managing building services</u>).	Address Tasks Two and Three
3. Critically evaluate energy procurement and management (<u>BIFM Competence 16 – Procurement</u>).	Address Task Three

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Question One

1.0. Information gather by client information

1.1. LTHW

The mains gas supply feeds three boilers and a combined heating and power unit (CHP). The CHP unit has a thermal store to regulate temperature. The hot water produced by the CHP unit, feeds into a heat distributor and subsequently a low loss header. The boiler feeds directly into the hot water pipework and into the header. The header then feeds the ten on-site air handling units (AHU). The hot water also feeds the internal spatial heating elements. The cooled return flow is returned to the boilers and CHP and the cycle is continued. Information gathered from drawing 9160-RD-M901 provided by Cardiff University.

1.2. Chiller and Chiller Units

The chiller is located on the external compound roof, above the seminar room and feeds into a low loss header. The header is fitted with a 300L expansion vessel. The chiller supplies the below plant. Information provided by Cardiff University.

Block	Floor	Plant Supplied
Auditorium Block	Ground Floor	• 2 X Cooling units
	Second Floor	• Low loss header • 300L Expansion Vessel • 7 X AHU's
	Roof	• 2 X External condensing room chiller units
Office Block	Ground Floor	• Low loss header • 12 X Chiller Beams
	First Floor	• 2 X Lan Room Cooling Units
	Roof	• 2 X AHU's • 2 X External condensing room chiller units



A Haddow (2021)

1.3. Chiller and Chiller Units

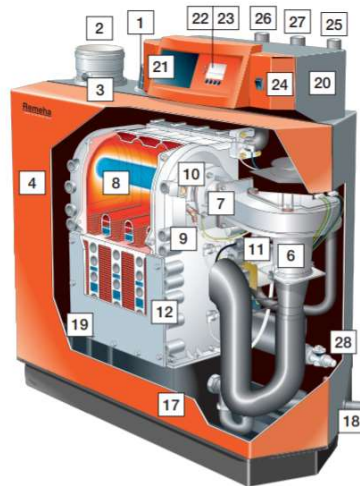
The main electricity supply is supplied directly from the neighbouring property known as the existing Julian Hodge Building. The supply is directed through to the CARBS panel board. Several sub meters have been installed which monitor the buildings energy use by area and appliance. Below is a table highlighting the various meters and areas covered.

Meter name:	Servicing Area:
DB Plant	Photovoltaic panels - Roof
Individual floor power and lighting	Lighting and power per floor.
BD IT 1/2	IT equipment per floor.
Mechanical Plant Meters	Mechanical plant – various locations
Chiller Supply Meters	Chiller – Roof
Lift Supply Meters	Lift supply - Roof
SMB 1	Stairs.
SMB 2	Lecture Theatre
CHP Unit	Fuel consumption / heat output / Electrical output
Water Usage	Internal and external water usage and rate (no data provided by the client)

1.4. On-site Plant Explained

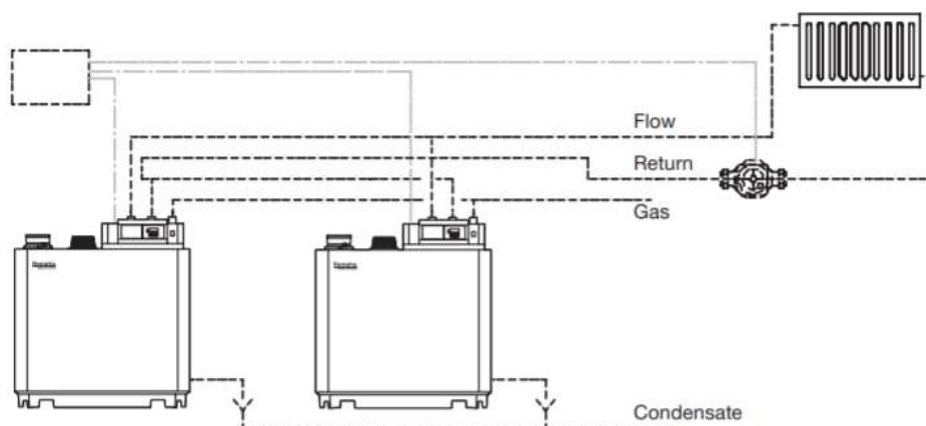
1.4.1. Modular Condensing Boilers

The heating system is fed by three Remeha Gas 210 Eco Pro free-standing gas fired high efficiency condensing boilers. Remeha (2020). The below diagram indicates the main components of the boiler system.



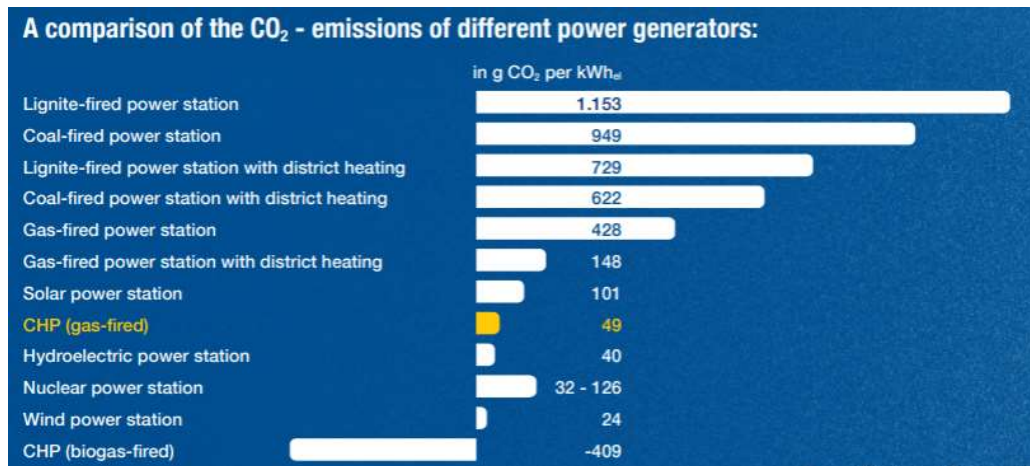
Remeha (2020)

The multiple boilers are installed to deal with the increased loading as the temperature becomes lower throughout the year. Mills (2019) suggests that installing multiple boilers can increase reliability and reduce boiler dependency during warmer months. Alongside this installing modular boilers provide a more flexible option within smaller plant rooms. BSRIA (2017). The basic principles of the condensing boiler are that air and gas is mixed. The mixture is then fired by a combustion ignition. The product of combustion is forced through the heat exchanger, transferring the heat to the system. Remeha (2020). The system then feeds the heat system within the building. As returned water to the boiler is at a cooler temperature. Latent heat is then released to pre-heat the returned water to increase the overall efficiency of the boiler. BSRIA (2017)



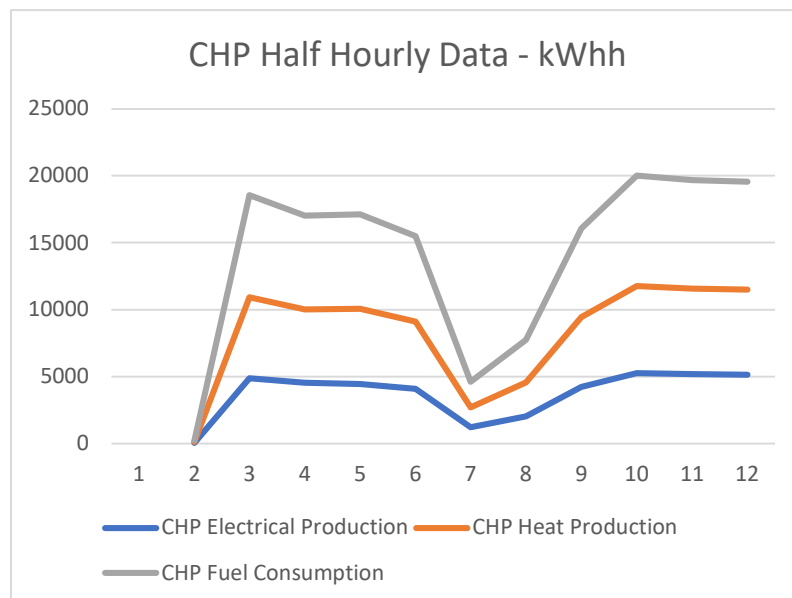
1.4.2. Combined Heating and Power Unit and Thermal Store

In addition to the condensing boilers a relatively small combined heating and power unit has been installed. According the manufacturer EC Power (2020) the XRGI model 9 is a combined heating and power (CHP) plant that works on the principles of cogeneration. The system works by producing heat and electricity and using the subsequent by-product of heat for spatial heating purposes. The CHP unit omits low CO₂ levels compared to similar power generators.



EC Power (2014)

At max capacity the CHP unit is producing just over 20kW of heat energy and 9kW of electrical energy. This is in line with the manufacturer's specifications.



Cardiff University (2019)

1.4.3. In Line Circulator Pumps

The hot water system is fitted with Grundfos Magna 3 rotor pumps. The pumps fitted are driven by electrical motors and are fitted with intuitive configuration to ensure optimal flow rates. Grundfos (2019). The pumps have been fitted with twin heads to provide built in back up. The pumps are fitted with variable speed drivers which control the flow rates of the hot water. BSRIA (2017)



Grundfos (2019)

1.4.4. Heating Pipes with Pipe Identification and Insulation

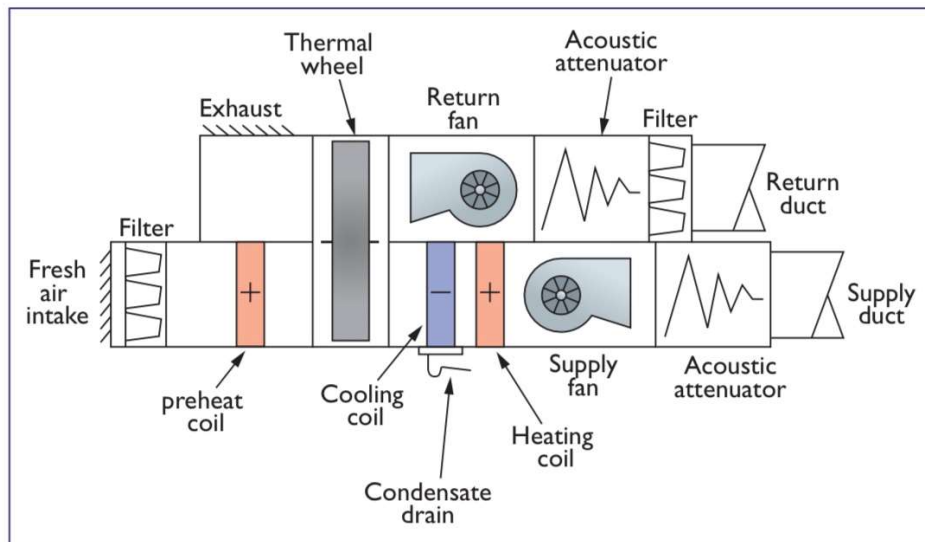
The heating pipes transfer the hot water throughout the building to the various heating solutions. Each pipe is fitted with identification tape which indicates the flow and return pipes. A phenolic foam insulation is fitted to prevent heat loss.



A Haddow (2021)

1.4.5. Air Handling Units and Associated Ducting

The buildings cooling and air supply is controlled by a multitude of air handling units (AHU). Generally, the AHU will be custom designed for the requirements of the building. BSRIA (2017). The on-site AHU's as a minimum will house supply and return fans, thermal wheels, energy recovery, filters and supply ducts.



Typical air handling unit.

BSRIA (2017)

1.4.6. Ventilation and Air Supply

For the habitable spaces within the building air displacement ventilation is delivered via floor swirl diffusers. Air is also extracted and supplied via high level circular return grills. All toilets are fitted with both supply and extract ducting. Natural ventilation is also present via the twin skin void and permanently open attenuation twin louvre grills. Information gathered from drawing 9160-RD-M102.

1.4.7. Domestic Hot Water

The hot water within the toilets and kitchens throughout the building are supplied by under-counter water heaters.

1.4.8. Photovoltaic Panels

A photovoltaic system has been installed to the roof space. The system consists of 7 strings of Yingli 250w monocrystalline module modules. The system is estimated to produce approximately 25854 kWhs of electricity per annum. The sub-meter installed recorded a production figure of 25255 kWhs

Question Two

2. Explanation of the building services maintenance

2.1. Size of the Organisation

The size of the organisation will influence how maintenance is procured. Organisations such as Cardiff University will have multiple sites all with various building services. Chas (2021) suggests that 56% of organisations in the UK have experienced skill shortages this year. The fact that the UK is currently experiencing a skill shortage could potentially make it difficult to directly employ persons with the skills and knowledge of the various plant equipment over the estate. This will lead to a forcing of the hand and will result in building maintenance being outsourced.

2.2. Complexity of Equipment

Maintaining complex equipment can be a specialist skill with many suppliers of plant suggesting approved maintenance suppliers. For instance, CHP units require annual maintenance to ensure the desired reliability and efficiency. The British Government (2021) suggests that *"a contract with the equipment supplier or one of the specialist O&M CHP companies is often considered to be an effective way of providing the necessary maintenance support that will ensure the long-term reliability and performance of the plant"*.

2.3. Value for Money

Costs associated with maintenance will be the main driving force when choosing in house operatives or an outsourced approach. With in-house workforces resulting in a constant cost, even during times of little to no need, a Reactive and Maintenance Framework may be the best solution. The benefits to this route are that all suppliers are regularly regulated in terms of cost and quality. Fusion21 (2020).

2.4. Procurement and Tendering

Procurement and tendering of contracts can be a lengthy process. For proactive maintenance the cost savings will potentially be seen, although for reactive maintenance, time is critical and waiting for tender process is not viable. FELP (2020) suggests that procurement timescales are on average 136 days. It is imperative that if contracts are being put in place for planned and reactive maintenance that the timescales are considered, and a contract is in place and renewed in line with contract renewal dates.

2.5. Planned Preventative Vs Reactive Maintenance

Planned reactive maintenance refers to a proactive approach to maintenance. Maintenance works are planned to take place at regular intervals. The Facilities Service Group (2020) suggests that planned preventative maintenance is cost effective overall due to issues being picked up before they become

larger and more costly issues. Although the age of the building and design can influence this. In addition to this Building Management Systems can be installed to major plant to monitor and provide early warning notices to building managers when systems are showing signs of failure. These systems work well with preventive planned maintenance.

2.6. Value of £ spent on maintenance per m2

Maintenance costs per unit is seen to be a way of benchmarking building maintenance costs. The National Audit Office (2013) states that primary indicators such as maintenance costs per m2 are indicators of overall cost efficiency of the estate's management function. For example, a building with an annual maintenance cost of £2,000,000 and a floor area of 2000m2 will have a maintenance cost per m2 of £1000/m2. This figure can be used annually to benchmark ongoing maintenance figures for the building and determine if greater investment is needed to reduce future annual figures.

2.7. Statutory Obligation and Compliance

The Institute of Workplace and Facilities Management (2017) Statutory Compliance for FM identifies through clear and concise tables the various compliance documents linked with building services plant throughout a building. Many of which will need to be carried out by an approved specialist within the associated field. As previously discussed, it may be difficult and expensive to directly employ the skills required.

2.8. Conclusion and Recommendations

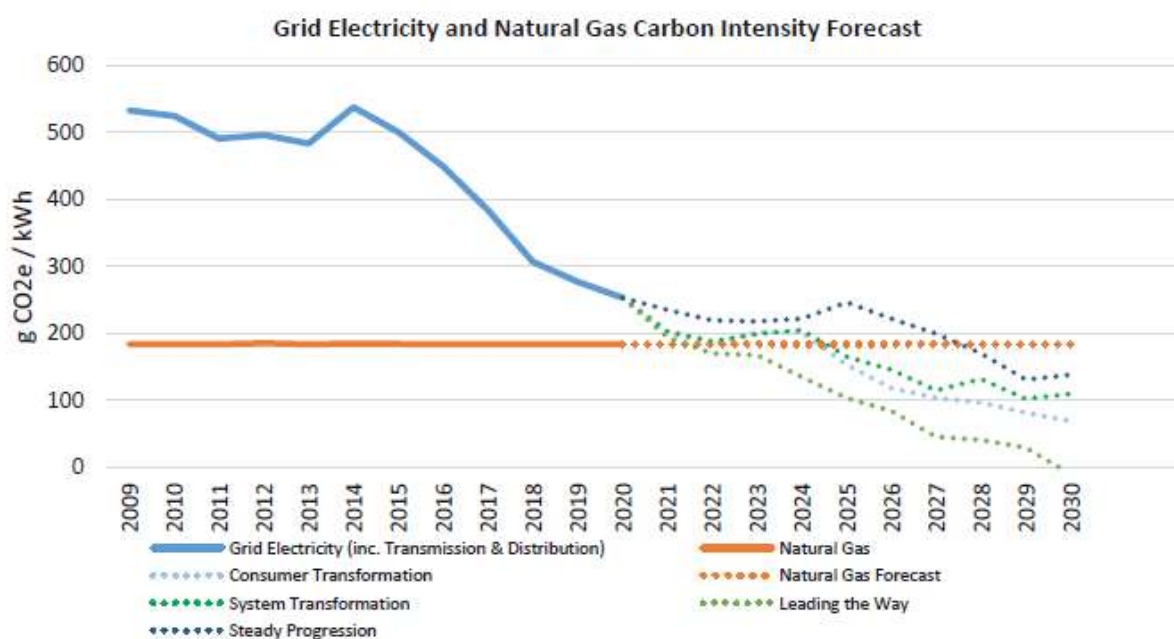
The recommendation put forward for Cardiff Universities maintenance arrangements would be to utilise a planned preventative approach. By utilising current and approved maintenance frameworks the university will be able to access skilled tradesmen and utilise pre vetted companies for both cost and quality. Thus, ensuring value for money. There will need to be a smaller direct labour presence to ensure smaller day to day maintenance is being achieved. The university may also employ a building surveyor to identify larger more costly activities. By utilising a framework contractor, the surveyor will be able to preventatively plan the works thus reducing overall costs.

Question Three

3. Energy Audit – CARBS Building

3.1. Drivers for Energy Efficiency and Renewable Energy

The carbon intensity with regards to electricity and gas is transforming. The amount of carbon produced per kWh of electricity will drop below gas in future years. The below graph published by the National grid (2020) highlights the potential scenarios of decline for the key energy services. This is an important consideration when undertaking energy audits in particular heating services.



National Grid (2020)

3.2. Cardiff University Energy Policies and Procedures

By declaring a climate emergency and signing the Sustainable Development Goal (SDG) Cardiff University have committed themselves to being carbon neutral by 2030 for scope 1 and 2 omission. Scope 1 and 2 omissions cover the direct burning of fossil fuels on site and the associated burning of fossil fuels off site to supply building energy. Cardiff University (2018).

With the aforementioned commitment by Cardiff University, considerations will be needed to underpin a route to carbon neutral by 2030. This report will investigate potential energy conservation measures that link with the common goal of reducing energy to the Cardiff University Estate. Based on the current consumption of the building considerable changes will need to be made to meet current targets.

3.3. Energy Analysis

The below table shows a breakdown of annual energy use, cost and carbon production for the Cardiff University Building for the years 2020 and 2021. The breakdown has been derived from current and past Display Energy Certificates. Electricity appears to be the majority cost and carbon producer within the building, although within 2021 the electricity consumption drops considerably. This is believed to have been due to less building users due to the coronavirus.

3.4. Existing Energy Use

2020	Energy kWh / Year	Cost £ / Year	Carbon Kg/Co ² / Year
Electricity	689,088.30	£87,927.67	242,256
Gas	586,239.30	£24,662.05	107,962
Total	1,275,327.60	£112,549.70	350,218

2021	Energy kWh / Year	Cost £ / Year	Carbon Kg/Co ² / Year
Electricity	241,695.15	£27,395.10	84,970
Gas	586,239.30	£24,662.05	107,962
Total	800,934.50	£52,017.15	192,932

Conversion factors provided by Carbon-Calculator.org.uk.



Full breakdown of the consumption rates, costs and carbon production within the building.

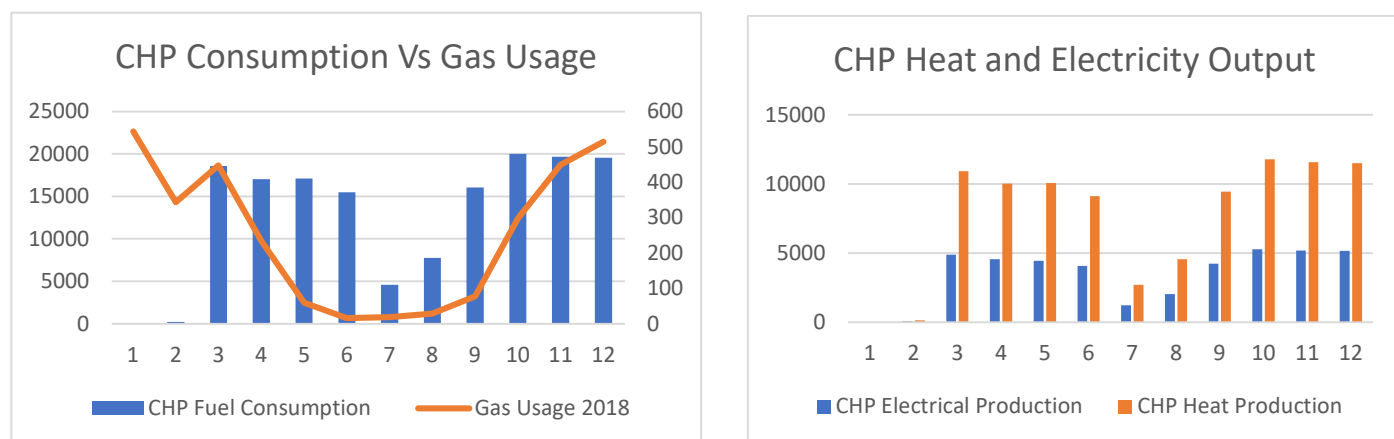
Based tariffs are unknown. For this exercise standard tariffs have been derived from British Business Energy (2021). All rates are inclusive of Climate Change Levy and the carbon factors used are the 2020 factors published by the Department of Business, Energy and Industrial Strategy.

3.5. Data Analysis

3.5.1. Combined Heating and Power

The graph below indicates the fuel consumption of the CHP unit against the previous year's gas usage.

The graph indicates that the consumption rate of the CHP unit is far greater than that of gas alone.



The second graph indicates the heat and power output of the CHP unit. At peak usage the power output is just over 5000 kWhh and the heat output is approximately 12000 kWhh. During the summer months the CHP unit could be seen to be consuming additional energy compared to running the condensing boilers alone. Subsequently additional power is supplied to the building and could be seen to offset the additional consumption and cost.

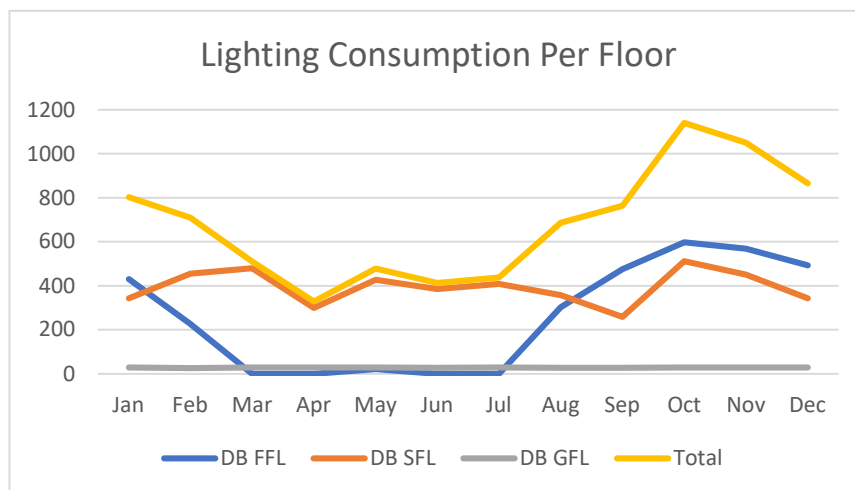
3.5.2. Lighting Consumption per Floor

The below graph indicates the consumption of energy used per floor within the building for the lighting. The graph indicates that the ground floor uses the least amount of energy with the first floor using most energy during peak time. The first-floor consumption appears to drop off from March 2020 to July 2020. Meter readings were taken during this period which would suggest that the usage of the lights was not needed due to increased daylight hours.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daylight Hours	08:24	09:53	11:48	13:49	15:35	16:31	16:05	14:33	12:35	10:34	08:49	7:55

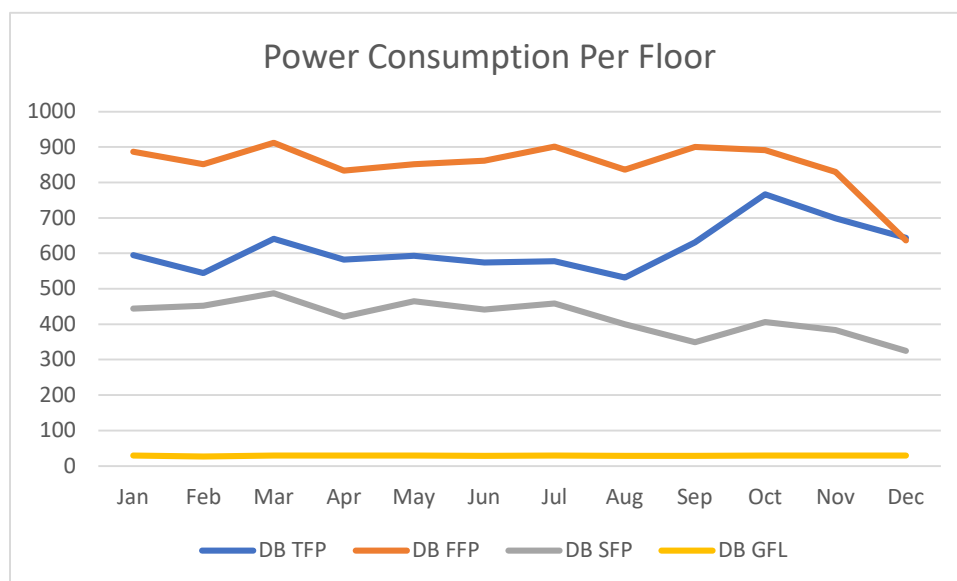
Cardiff Climates (2020)

As the above data suggests from March to September, the daylight hours show a considerable increase, resulting in less use of the buildings lighting system. Although the data appears to read very low to zero usage within the months of March and July which may indicate a potential issue with the meter.



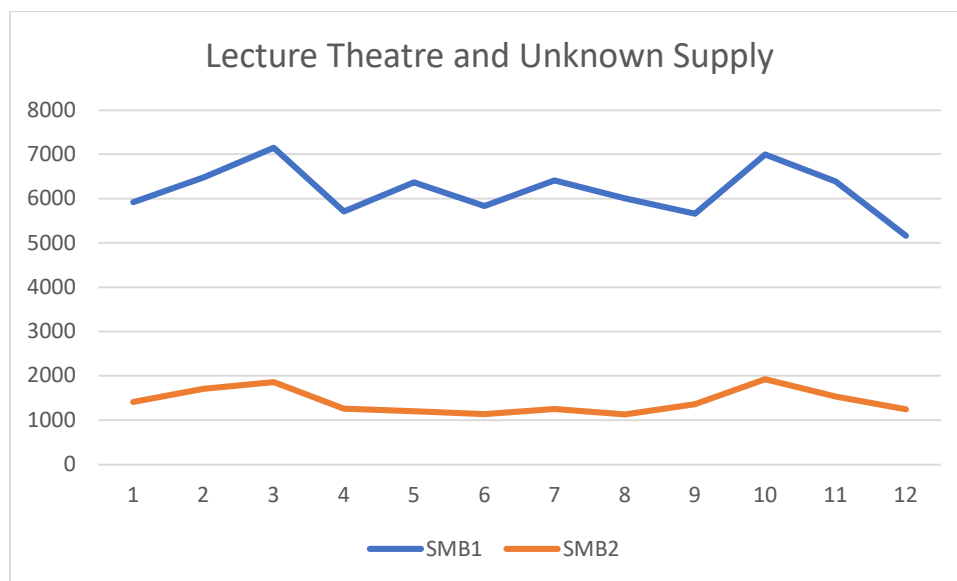
3.5.3. Power Consumption per Floor

The below graph indicates the power consumption per floor. As with the above lighting graph the ground floor appears to use very little power. The other floors appear to use considerable but normal amount of power per floor with the first floor consuming approximately 900 kWh. This is likely to be due to the first-floor housing much of the office space and the lecture theatre.



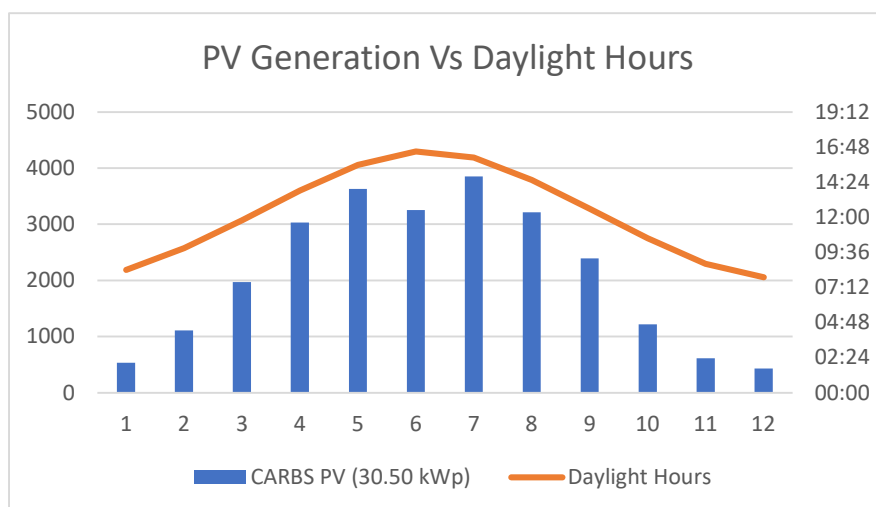
3.5.4. SMB 1 and SMB 2

The below graph indicates the kWhh usage of the lecture theatre and the ancillary power such as sockets and hand dryers. The lecture theatre consumes a relatively steady amount of energy with relatively low energy demand for the space. The ancillary supply named SMB1 is consuming a considerable amount of energy annually. Further investigation into the direct sources is needed.



3.5.5. Photovoltaic Panels

The below graph indicates the generation of power compared to daylight hours. The graph indicates that the photovoltaic panels are producing power in line with the daylight hours. Checks within the O&M manual have shown that the production of power annually is in line with the installer's specifications.



3.6. Data Gaps

BS EN 16247:1 states that reliable data should be collected and should be traceable to the origin and process. Within the data provided by Cardiff University there are several discrepancies and untraceable meters. The standard also sets out the parameters for listing additional data needs for later analysis. One recommendation would be for the meters installed to be serviced to ensure the meters are running correctly. In addition to this all meters should be coded to provide traceability. This process should be completed in line with the schematic situated within the plant room. A full list of additional data required has been prepared below.

Meter No:	Meter Name:	Reasoning:
3019	CARBS Ext Water Rate	By investigating differences in the water rates external leaks can be identified.
2362	CARBS Ext Water Usage	The correlation of the water usage can also assist with finding external water leaks.
3020	CARBS Internal Water Rate	By investigating differences in the water rates internal leaks can be identified.
		It is estimated that 25% of the UK's water system is being lost by leaks. Building.co.uk (2019). There is significant savings to be made when identifying leaks.
2363	CARBS Internal Water Usage	The correlation of the water usage can also assist with finding internal water leaks.
1807 & 1811	CARBS Mech CP GF and AHU	By understanding the usage of the mechanical plant energy conservation measures could be produced with investment grading and payback times.
1810	CARBS Chiller	Daikin (2012) suggests that refrigeration, ventilation and space cooling can make up at least 19% of an organisation's energy consumption. Considerable savings can be made.
1812	CARBS DB TFL	Unable to audit the lighting within the third floor.
1818	CARBS IT 1	Unable to audit and compare power consumption from IT services.
3022	Unknown	Meter was not audited due to traceability issues.
2087	Unknown	Meter was not audited due to traceability issues.
SMB1	Unknown	Meter was not audited due to traceability issues.

3.7. Benchmarking

With the use of CIBSE guide F and CIBSE Energy Benchmarking Tool Dashboard the below details have been obtained and compared to the Cardiff University Business School.

With the use of the current display energy certificate current annual energy usage per fuel has been determined.

Energy Use 2021	Electricity	Gas
Annual Energy Usage kWh/m2/year	47	114
CIBSE Energy Benchmarking Figure – Good Practice	113	110
CIBSE Energy Benchmarking Figures – Typical Practice	129	132

Energy Use 2020	Electricity	Gas
Annual Energy Usage kWh/m2/year	134	114
CIBSE Energy Benchmarking Figure – Good Practice	113	110
CIBSE Energy Benchmarking Figures – Typical Practice	129	132

CIBSE Guide F (2012) states that monitoring and targeting provides mechanisms for the long-term management of energy use and for highlighting potential improvements in the efficiency of the building. More in depth methods of benchmarking can be used when the data quality is improved. For this audit the display energy certificate has been used.

The above tables indicate that the building has significantly improved its electricity usage in 2021. This data is an anomaly due to the coronavirus and less footfall within the building during 2021. The more realistic usage would be that of 2020. The usage within 2020 indicates that the building is above typical practice usage of electricity and slightly better for gas.

3.8. Areas with low and future investment grade opportunities

3.8.1. Lighting

The Cardiff University Business School makes good use of natural lighting throughout. The light fittings were deemed to be LED. By calculating the kWh / square foot for lighting, the lighting system fitted in association with the natural lighting was deemed to have very little to no opportunities for improvements.

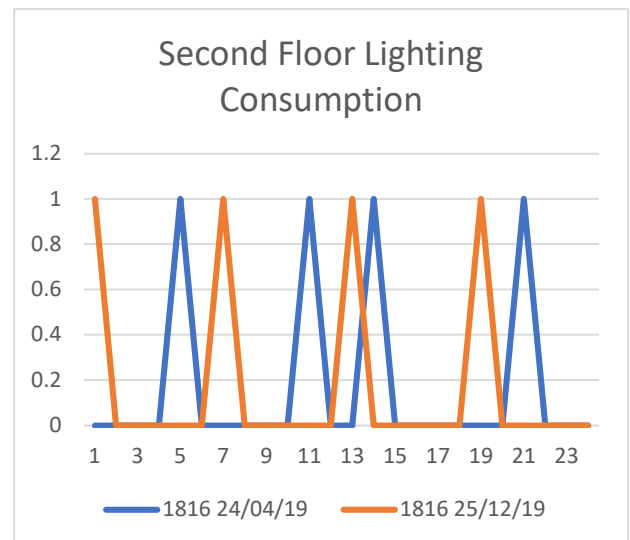
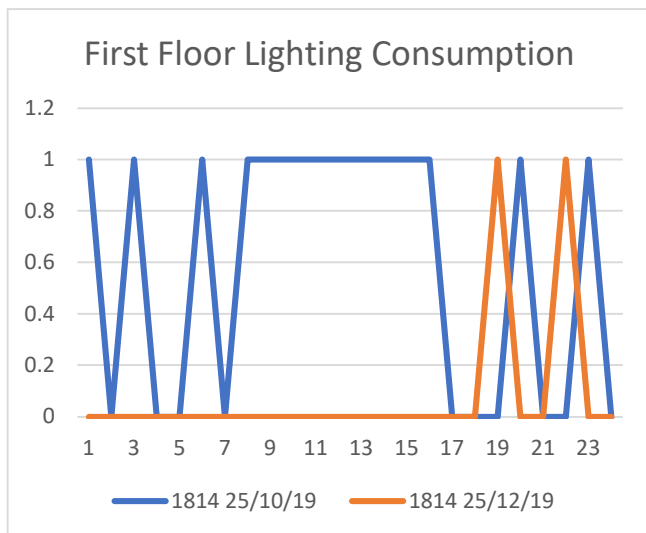
Calculations

Building footprint minus one floor to account for the missing data = 3856.83

Total kWh per year for lighting = 16376

Total kWh per square foot $16376/3856.83 = 4.28$ kWh / sqft.

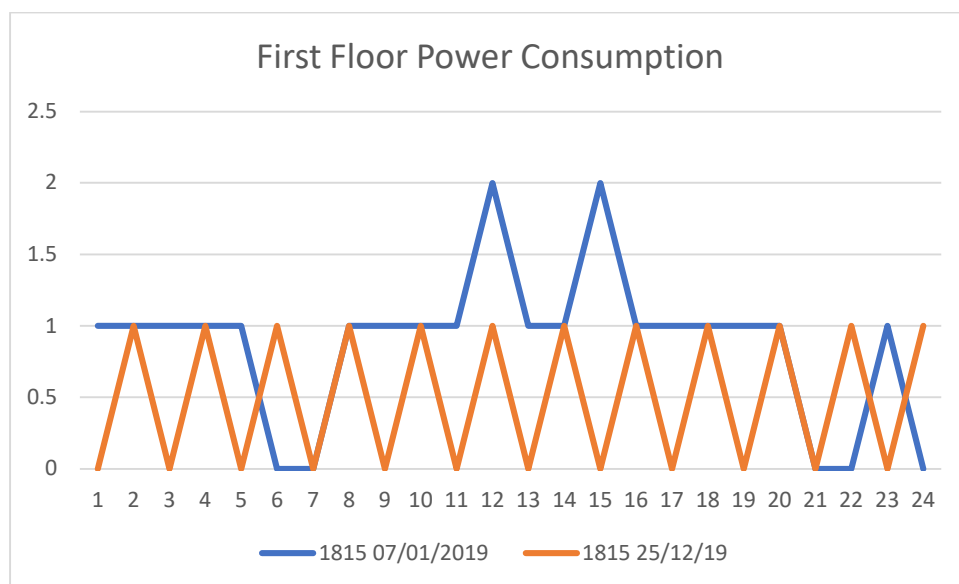
iota COMM (2020) indicates that a typical consumption for lighting per square foot is 7 kWh. The business school appears to be considerably better than average.

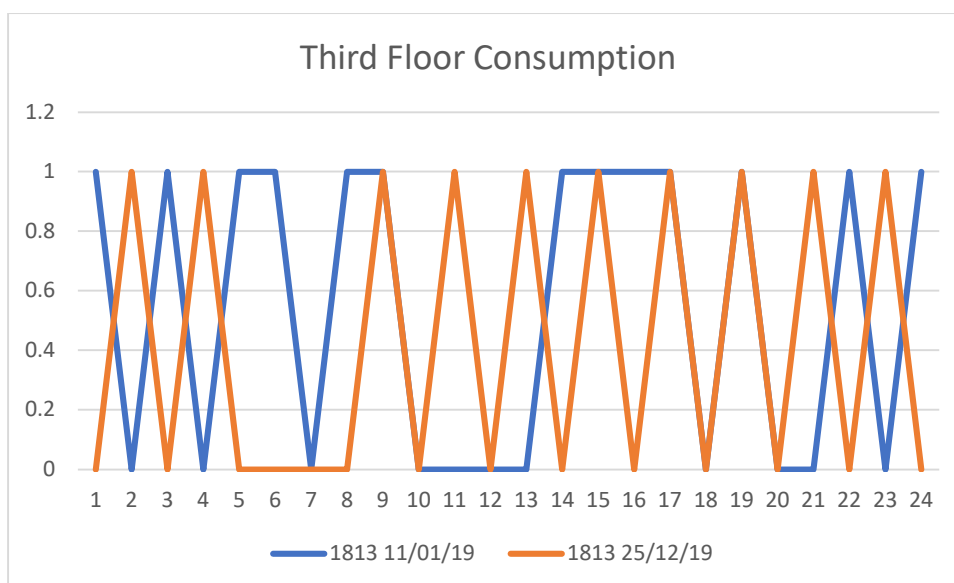


The graph indicates a base-load per floor of approximately 0.5 kWh for lighting. Consumption remains constant throughout the night; this would indicate that lights are on within the building during out of office periods. It is suggested that a night-time survey is carried out to identify an unnecessary lighting.

3.8.2. Electrical Power and Office Equipment

The base-load for power within the building appears to be 1 kWh per floor. The below graph indicates a constant power consumption throughout a 24-hour period. There is also a power consumption during Christmas day which suggests a constant power supply within the building.



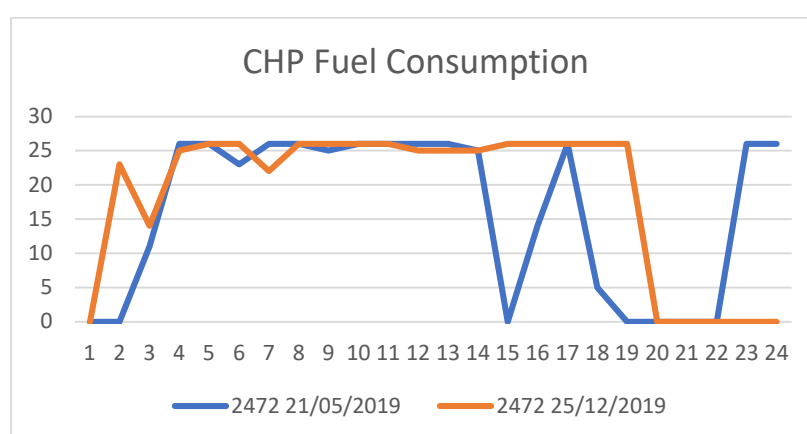


With there being a constant intermittent load within the building, further investigation is required to analyse the use and to determine if improvements can be made to reduce the ongoing consumption.

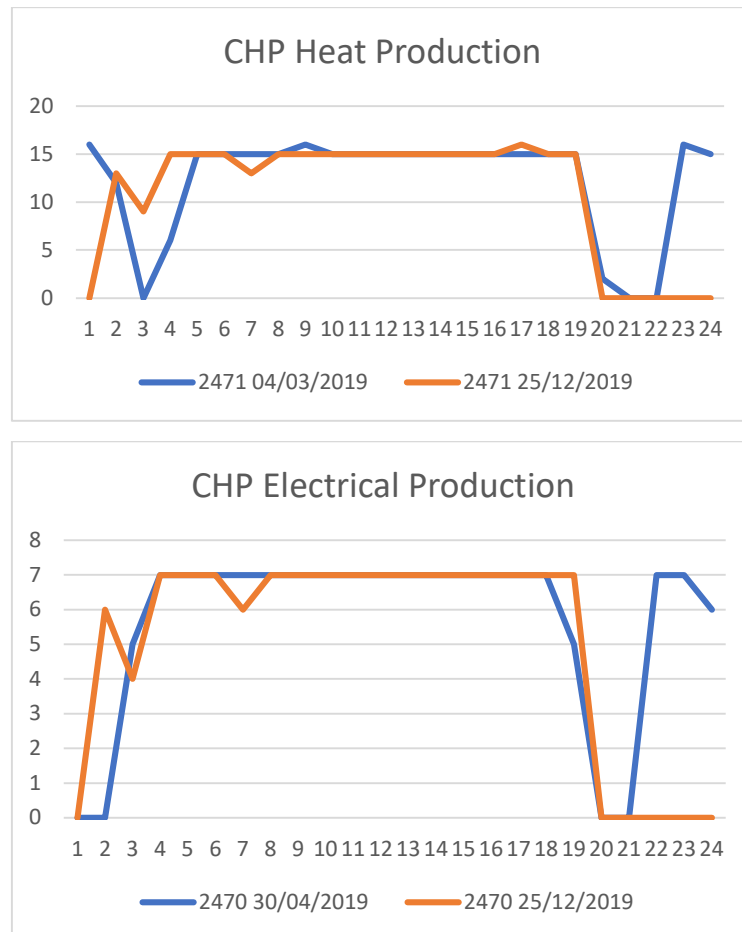
3.8.3. Heating and Hot Water

The Cardiff University Business School has a CHP unit fitted and is being used as the primary source of heat. CIBSE Guide F (2012) suggests that CHP units should always operate as the lead boiler to maximise carbon savings. The guide also suggest that the unit should be sized accordingly to take the heating base-load as a minimum.

The below graph identifies that the CHP boiler is running at a steady capacity throughout warmer and colder months. This would suggest that the CHP unit is meeting the base-load. Although a comparison of the gas consumption prior to the use of the CHP unit would suggest an increase in overall gas consumption. Please see CHP Consumption Vs Gas Usage graph above.



To fully understand the benefits and drawbacks of the CHP unit in comparison to the condensing boilers, additional data is required to understand gas consumption with the CHP unit and without the unit. One drawback identified with the CHP unit is that the boiler is producing heat and power during unoccupied building hours. As the below graphs show, power and heat are both being produced from 1am till 8pm. This can be seen as wasteful especially during days such as Christmas day when the building will be unoccupied.



The investment grade and opportunity identified for the heating and hot water would be to replace the CHP unit with an air source heat pump or a biomass boiler. System transformation only achievable at the end of the existing CHP's useful life. Please see section 3.10. for details.

3.9. Energy Conservation Measures

The following section details the energy conservation measures (ECM's) that have been identified following the recent site visit and the energy data provided by Cardiff University. Some areas have not been assessed due to access issues on-site and the data provided limited full calculations of some opportunities.

3.9.1 ECM Details

3.9.2. Energy Management / Behavioural Change

The audit revealed opportunities for reducing energy use through behavioural change. Staff and student engagement can yield savings of up to 5% on overall energy costs. Carbon Trust (2020). This is generally achieved via designed and phased awareness training. Staff incentives can also improve engagement.

Several examples within the staff offices included IT equipment left on standby, fans and heating equipment present.

Sensors, smart plugs and improved staff behaviours can be implements to tackle this energy waste. Carbon Trust (2020).

3.9.3. Biomass Boiler

Biomass boilers burn biofuels such as wood chip, pellets and wood logs to heat hot water. The system can be connected to traditional wet heating systems. Due to the large heat loads at the Cardiff University Business School and the complexity of the pipework configuration, biomass boilers are suggested as a low carbon upgrade.

The biomass can be sourced locally, although regular maintenance is required to remove ash and re-feed the biomass. Pellet storage and delivery requirements will need to be considered. Carbon Trust (2020).

The CO₂ produced during the burning of the biomass is effectively offset during the growing of the fuel. This results in biomass producing less than one tenth of the carbon emissions of gas.

Calculations

Wood chip costs – 2.9 p/kWh – Spon's Architects and Builders price book 2020

Biomass Boiler Cost - £265/kw – Spon's Architects and Builders price book 2020

Boiler sized to the same rating as current install

New boiler assumed to be 90% efficient

3.9.4. Air Source Heat Pump

Heat pumps transfer low grade heat from the environment and converts it into higher temperatures and transfers it into internal spaces. The coefficient of performance is the ratio of heat to electricity output and can reach values of 4 and above, which results in efficiencies of 400%. This means heat pumps are much more efficient than conventional boilers. The Renewable Energy Hub (2020).

Heat pumps are becoming an ever-increasing solution to space heating with the technology being implemented into over 46,000 buildings across the UK. Carbon Trust (2020).

Calculation Assumptions

2.9 - Coefficient of Performance

Capital Cost - £575 pe kW – Spon's Architects and Builders price book 2020

3.9.5. Optimisation of sub-metering and monitoring & targeting

CIBSE Guide F (2012) highlights energy data to be an essential part of assessing building performance. The guide also suggest that the data quality is important. The Cardiff University Business School has a good number of meters fitted all within areas of importance when carrying out an energy audit. It is imperative that these meters are identified and serviced to ensure data is being captured. By understanding the buildings various consumption rates specific monitoring and targeting techniques can be adopted to identify poor performance and set reduction targets.

3.10. Investment Grade Opportunities

Due to the missing data and traceability issues with the meters the below investment grade opportunities are based on potential for saving energy. The report is a technical assessment of the opportunities to save money and carbon. The opportunities have been developed to improve energy efficiency and will require further detailed feasibility analysis before implementation.

Opportunity	Est. Annual Energy Savings			Cost (£)	Simple Payback (Years)
	£	tco2e	kWh		
Energy Management	£2,300	4.3	6900	0	0
Biomass Boiler	£33,600	199.6	100600	£238,500	7.1
Air Source Heat Pump	n/a	24.4	155,100	£77,000	n/a

Figures and calculations established from the Carbon Trust (2020)

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