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Client	Borough of Broxbourne Council
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Glossary

Abbreviation	Meaning
A/C	Air Conditioning
AHU	Air Handling Unit
ASHP	Air Source Heat Pump
AWHP	Air-Water Heat Pump
BMS	Building Management System
CAPEX	Capital Expenditure
CDD	Cooling Degree Day
CHW	Chilled Water
DHW	Domestic Hot Water
ECM	Energy Conservation Measure
EnPI	Energy Performance Indicator
FCU	Fan Coil Unit
GSHP	Ground Source Heat Pump
HH	Half Hourly
HDD	Heating Degree Day
LCCA	Life Cycle Cost Analysis
LED	Light Emitting Diode
LTHW	Low Temperature Hot Water
M&E	Mechanical & Electrical
OPEX	Operational Expenditure
PIR	Passive Infrared
PV	Photovoltaic
VSD	Variable Speed Drive

Executive Summary

Figure 1: Site Photo

This report contains the results of a decarbonisation study for Bishops College, which has been commissioned by Borough of Broxbourne Council. It documents the findings of a site audit undertaken by Concept Energy Solutions and contains details of the building fabric, building services equipment and plant as of August 2023.

Space heating to the Old Building is provided by gas boilers, most of which are considered end of life. The New Building is heated by both gas boilers and electric reheat coils in supply air ductwork. Lighting is mostly from efficient T5 fluorescent or LED fittings. The New Building is believed to have insulated cavity walls and the old building has solid brick walls, and roof insulation is believed to be below current standards throughout. Single glazing is also installed throughout.

The gas consumption of the site in the 2022/23 financial year was 824,706 kWh and electricity consumption was 565,794 kWh, with associated total emissions of 259.9 tCO_2e. It is noted that these values include consumption relating to the leased areas.

Information collected during the site audit was used to create a bulk energy simulation model of the building using industry standard software RETScreen. The output from the model has been compared with historic consumption data, to check its accuracy.

A number of different decarbonisation measures have then been applied to the model to assess likely carbon reduction impact. We have applied a carbon reduction hierarchy (see section 13.1) to the measures considered in this report. This hierarchy applies zero costed saving measure and costed efficiency measures before the use of low carbon heating technologies and on-site generation.

The only zero cost measure identified is to adjust heating controls for both the New Building and Old Building, where the boiler operating hours could be reduced to match occupancy hours.

We have identified a number of costed energy efficiency, low carbon heating and renewable energy measures, which we believe are technically feasible for the site. We have estimated the costs and savings for these projects and calculated the Net Present Value for each investment, as shown in Table 1.

The low carbon heating options include Air to Water Heat Pumps (AWHP), Air to Air Heat Pumps (AAHP), Ground Source Heat Pumps (GSHP), Water Source Heat Pumps (WSHP), direct electric heating, biomass boilers and solar thermal. The WSHP option has the highest annual carbon saving of ca. 40.1 tCO_2e.

Measure	Persistence Factor	Guideline Cost, £	NPV, £	Annual Carbon Saving, tCO_2e
Energy Efficiency				
Replace Chamber AHU belt driven fan with direct drive fan	24	5,500	13,222	0.4
Plant room pipe and valve insulation	23	2,600	13,687	0.9
Roof insulation (New Building)	30	74,100	-17,196	2.3
Roof insulation (Old Building)	30	13,500	-8,855	0.2
Glazing	28	114,600	22,246	5.0
Low Carbon Heating				
AWHP (New Building)	20	1,175,600	-978,358	36.4
AWHP (Old Building)	20	725,400	-661,573	11.4
AAHP	20	1,316,400	-1,119,158	36.4
GSHP	25	1,491,500	-1,169,113	37.7
WSHP	25	1,259,500	-815,357	40.1
Direct electric heating (New Building)	10	250,800	-697,069	7.1
Direct electric heating (Old Building)	10	208,600	-343,305	2.4
Biomass boiler (New Building)	20	243,100	-548,135	27.7

Measure	Persistence Factor	Guideline Cost, £	NPV, £	Annual Carbon Saving, tCO_2e
Biomass boiler (Old Building)	20	163,200	-253,409	8.7
Solar thermal	25	31,200	591	0.6
Renewable Energy Generation				
Solar PV 22kWp	23	103,600	83,084	4.0
Solar PV 19kWp (if solar thermal also implemented)	23	98,300	62,927	3.5

Table 1: Summary of costed saving measures

Contents

1 Introduction

1.1 Background

Broxbourne Borough Council has commissioned Concept to provide building decarbonisation study of their offices at Bishops College. The primary purpose of these reports is to identify suitable heating decarbonisation options that could form the basis of an application for funding under the Public Sector Decarbonisation Scheme (PSDS). This scheme requires a 'whole building approach' to heat decarbonisation and in addition to low carbon heating will fund eligible energy efficiency and on-site renewable energy measures.

This is the decarbonisation study report for the Bishops College, completed following a survey of the site in August 2023.

1.2 Site Details

Bishops College is located in, Churchgate, Cheshunt, Waltham Cross EN8 9XB and comprises of several buildings. The New Building is a four-storey building containing several tenants but Council owned, built in 1987. The ground floor (level 1) is occupied by a private clinic and by the Probation Service. The first floor (level 2) is occupied by the Council and is office space. The second floor (level 3) is occupied by the NHS. The third floor (level 4) is the plant room, containing boilers and AHU plant. Most of the building is served by main plant, while the private clinic has its own HVAC plant which was not surveyed.

The Old Building is a grade 2 listed building, mostly 19th century constructed. It comprises Octagonal Suite, Huntingdon Suite, Ingram House and Spanish Ambassador's House. Only a couple of rooms are actually occupied by the Council, with the rest leased space. The top floor was unoccupied. All spaces are served by the Council's plant.

Beaufort Suite is a standalone building next to the car park adjacent to the road. The building age could not be confirmed but it is believed to have been constructed in the 19th century. This building is used for private hire functions only, and is infrequently used.

The Print Room contains some commercial printing equipment. The building age is unknown but it is believed to have been constructed in the late 19th or early 20th century.

The gross internal floor area of the New Building Council's area is ca. 3,197m^2 according to the most recent Display Energy Certificate, which has a rating of C. The areas of Fertility Clinic, Probation Office and NHS Office are ca. 533 m^2, 298 m^2 and 330 m^2 respectively.

The gross internal floor area of the Old Building, Ingram House, Spanish Ambassador's, Beaufort Suite and Print room are ca. 1,827m^2, 434m^2, 143m^2, 187m^2 and 108m^2 respectively.

The typical occupancy hours of the Council-occupied areas at the time of the survey are 09:00hrs to 17:00hrs Monday to Friday, with no occupancy at weekends. The occupancy hours of leased areas are not known but are expected to be similar to those of the Council occupied areas.

1.3 Timing of Audit

An inspection of the building was carried out by Jamie Green of Concept Energy Solutions on 2nd August 2023. We gratefully acknowledge the assistance of Mihnea Pruna, Sustainability Officer at Borough of Broxbourne, during the survey process.

2 Objectives Priorities and Methodologies

2.1 Survey Objectives

The purpose of the survey and audit is to:

- identify current building services equipment and operation;
- identify energy savings opportunities, including capital works and operational changes;
- identify improvements that can reasonably be made to building fabric;
- estimate the savings from any recommendations in terms of kWh, CO_2 equivalent and cost;
- recommend potential decarbonisation pathways, and
- quantify any residual emissions after implementation of all recommended measures.

2.2 Survey Methodology

A site survey was conducted in which all major energy consuming plant was identified and non-intrusively inspected.

Details of building services were collected on site on 2nd August 2023, supported by information provided by Broxbourne Borough Council.

The building fabric was also visually inspected; scaled site plans were obtained, wherever available, for off-site measurement of building heat loss areas. A dimensional survey of a representative sample of openings and elevations was conducted during the site survey for comparison with scaled floor plans provided.

Baseline energy consumption was calculated for electricity and gas based on available consumption data provided by the client, in order to quantify Scope 1 and Scope 2 emissions. Where consumption data has not been provided, baseline emissions could not be confirmed.

The information gathered has been used to produce a Bulk Energy Model of each of the buildings using industry standard software: RETScreen. Where actual heating fuel consumption data has been provided, the model was compared with the calculated baseline consumption.

A number of energy saving opportunities were identified during the site visit and savings from these have been estimated using a combination of RETScreen modelling and bespoke calculations. Measures have been grouped under the following energy hierarchy:

1. Operational energy savings
2. Building energy efficiency measures
3. Low carbon heating
4. On-site renewable energy generation

The modelled savings were used to produce a number of decarbonisation pathways.

3 Site Energy Consumption & Cost

3.1 Summary

The table below shows the total site energy consumption of the New Building and Old Building combined, Ingram House/Spanish Ambassador's House, and Beaufort Suite for the financial year 2022/23 from April 2022 to March 2023. Data is taken from actual site consumption provided by the Council.

It should be noted that the electricity consumption is based on the main revenue meters for the New and Old buildings, which therefore includes leased areas which are outside the operational control of the Council. These are outside the scope of this study and as sub-metering data has been provided, will be subtracted from the baseline consumption for modelling purposes.

Electricity cost data is based on actual invoiced costs, including CCL and energy bill relief scheme rebates, but excluding standing charges and VAT.

Gas cost data is based on average rates inferred from total annual charges. No breakdown of these charges has been provided and the annual figures are assumed to be inclusive of CCL and standing charges but exclusive of VAT.

For Beaufort House only, the electricity and gas costs have been entirely estimated, based on an electricity rate of 32p/kWh and a Gas rate of 12.6p/kWh as charged to other areas of the site.

Building	Utility	Energy		Cost		CO_2e emissions	
		kWh	%	£	%	Tonnes	%
New Building and Old Building	Electricity	547,835	46.4	184,744	70.8	105.9	47.8
	Gas	632,602	53.6	76,062	29.2	115.5	52.2
	Total	**1,180,437**	**100**	**260,806**	**100**	**221.4**	**100**
Ingram House/Spanish Ambassador's	Electricity	11,825	6.8	3,732	15.5	2.3	7.2
	Gas	161,354	93.2	20,331	84.5	29.5	92.8
	Total	**173,179**	**100.0**	**24,063**	**100**	**31.7**	**100**
Beaufort Suite	Electricity	6,134	16.6	1,963	33.6	1.2	17.4
	Gas	30,750	83.4	3,875	66	5.6	83
	Total	**36,884**	**100**	**5,837**	**100**	**6.8**	**100**

Table 2: Energy Consumption during financial year 2022/23

CO_2e Emissions have been calculated from conversion factors of 0.19338 kg CO_2e per kWh for electricity and 0.18254 kg CO_2e per kWh for gas, which were obtained from the 2022 government DESNZ (formally BEIS) dataset of conversion factors for greenhouse gas reporting.[1]

3.2 Electricity supply

3.2.1 Supply description and metering

Most of the site is supplied by a single 3-phase incoming supply located in the New Building.

[1] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2022

There is one revenue meter recording half hourly (HH) site consumption in both the New Building and Old Building. The meter is located in a ground floor switch room accessed via the facilities office.

There is a separate 3-phase supply with a revenue meter located at basement level underneath Spanish Ambassador's House, serving both Spanish Ambassador's Suite and Ingram House. This is a non-half hourly meter and reading records have been provided.

The Beaufort Suite has an analogue single phase revenue meter located in a meter cupboard by the main hall. This meter is manually read but the associated MPAN has not been confirmed.

There are various sub-meters recording consumption in leased areas of the New Building, including the ground floor probation office, the fertility clinic and Level 3 (NHS). There is also a sub-meter for the Old Building located in a basement level switch room. These meters are read on a monthly basis and reading records were provided to Concept during the survey.

The revenue meter details are as follows:

Utility	Building	MPAN	Meter Serial Number
Electricity	New Building and Old Building	1014572704780	03002520
Electricity	Ingram House/Spanish Ambassador's	1013044790637	E14ML12258
Electricity	Beaufort Suite	TBC	P967-83 05587

Table 3: Electricity meter details

The suppliers have not been confirmed for each of these supplies but charging detail has been provided for the main two supplies (MPANs 1014572704780 and 1013044790637) as of June 2023, which confirms the following contractual rates:

MPAN	Day Rate (p/kWh)	Night Rate (p/kWh)	Evening and Weekends (p/kWh)	CCL* (p/kWh)
1014572704780	32.80	31.22	N/A	0.775
1013044790637	34.45	31.23	31.27	0.775

*Applied to day and night energy

Table 4: Electricity cost details

The invoice detail provided confirms a current available supply capacity for the main meter (New and Old Buildings) of 232kVA. The maximum demand recorded on the associated revenue meter was 147.6kW.

The invoice detail provided for the Ingram House meter does not include an available supply capacity charge and the associated revenue meter was not configured to display maximum demand.

3.2.2 Monthly consumption profile – New Building and Old Building

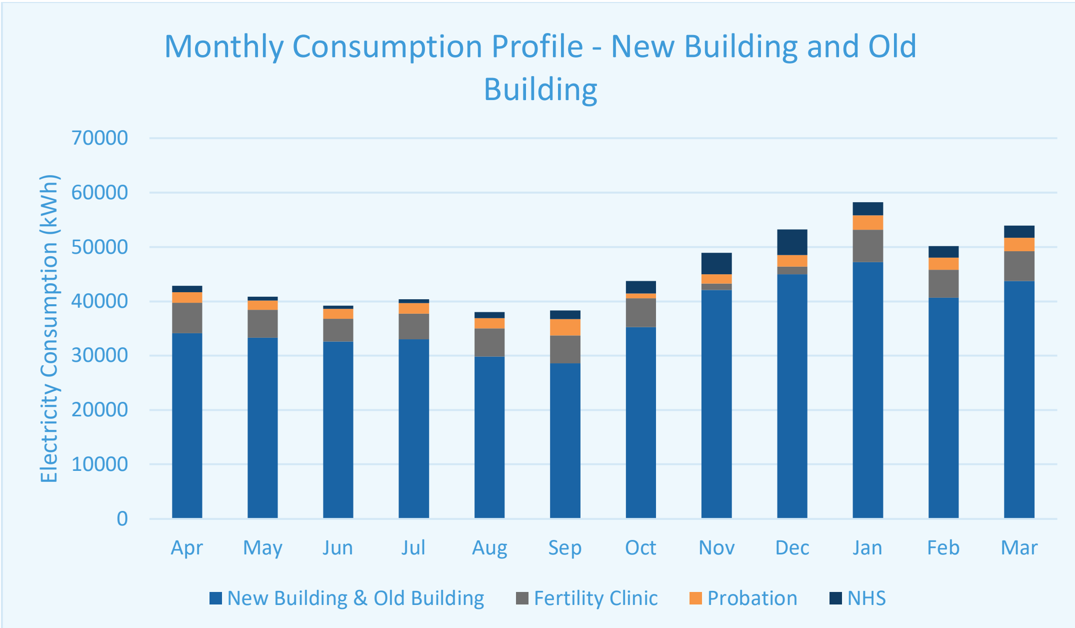


Figure 2: Monthly Electricity Consumption - New Building and Old Building

Manual readings for the fertility clinic, probation services, and NHS are provided for April to December 2022. We assumed that the readings are provided at the beginning of each month rather than the end. The consumptions in January to March 2023 are estimated based on the proportions of consumptions in the previous months.

The monthly profile shows relatively consistent monthly consumption throughout the year, with a clear increase in winter. As AHU reheat coils and DHW are electric, the electricity consumption for heating would be increased in winter.

The overnight electricity consumption is recorded with a night reading and averaged 22% of the overall electricity consumption throughout the year.

3.2.3 Monthly consumption profile – Ingram House/Spanish Ambassador's

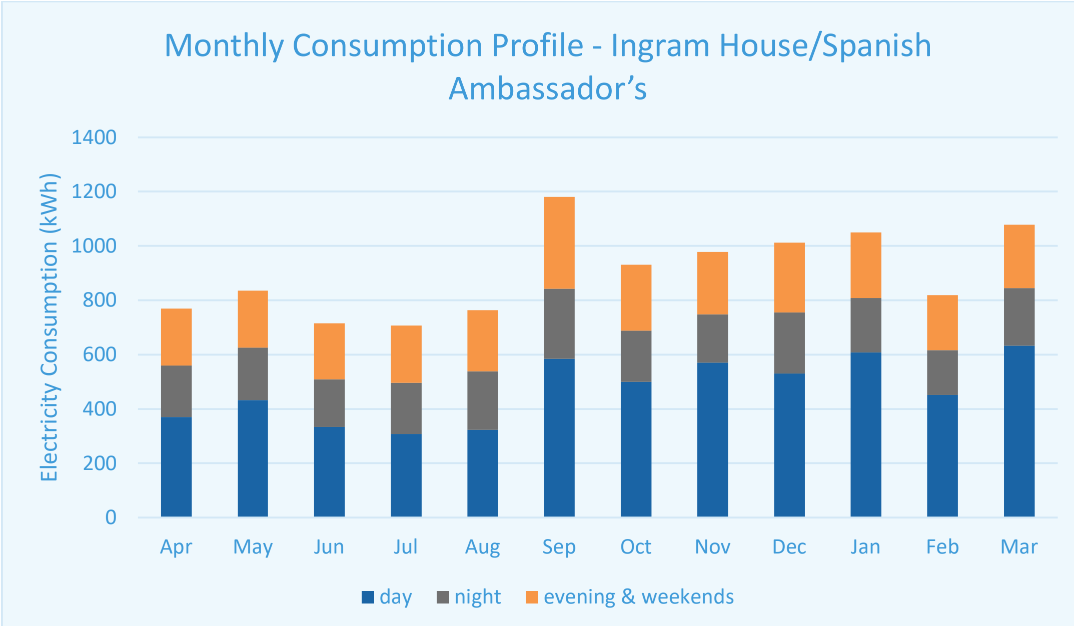


Figure 3: Monthly Electricity Consumption - Ingram House/Spanish Ambassador's

The monthly profile shows a consistent low usage throughout the year, with a slight increase in September.

The overnight electricity consumption is recorded with a night reading and averaged 22% of the overall electricity consumption throughout the year.

3.2.4 Monthly consumption profile – Beaufort Suite

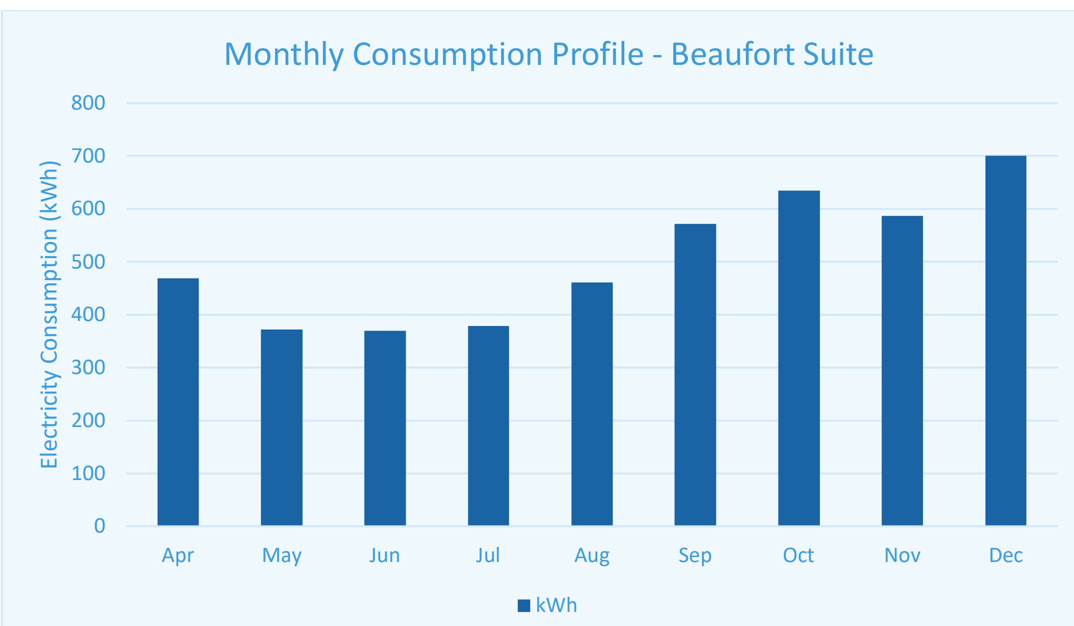


Figure 4: Monthly Electricity Consumption – Beaufort Suite

Manual readings of Beaufort Suite are provided from April to December 2022. We assumed that the readings are provided at the beginning of each month rather than the end.

The consumptions are subject to the number of functions as this building is used for private hire functions only.

3.2.5 Weekly consumption profile

Half-hourly data is available for the main meter serving the New and Old buildings only. This data has been analysed to identify usage patterns and potential energy wastage. Analysis has been undertaken for a typical winter and summer week.

Data for the week commencing 16th January 2023 has been take as representative of a typical winter week. Likewise, data covering the week commencing 8th August 2022 represents a typical summer week.

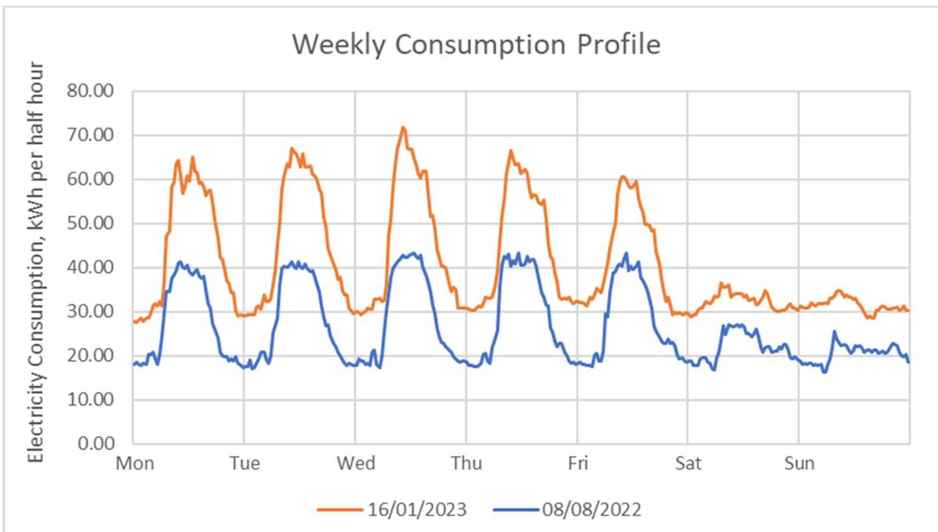


Figure 5: Summer / Winter typical week half-hourly analysis

The baseload appears to be ca. 60kW in the winter week and ca. 40kW in the summer week. This could be due to space temperature controls or pumps being left ‘in hand’ in the winter, or else some seasonal use of plant in leased areas such as the fertility clinic, which could not be confirmed. The peak demand is ca.140kW in the winter week and ca. 88kW in the summer week. Both weeks show a similar pattern throughout the week with reduced operational hours at the weekend, while the winter week had a greater consumption as part of the heating demands are provided by electric heating coils.

3.3 Gas supply

3.3.1 Supply description and metering

There is one main gas supply to the New Building. The revenue meter for this supply is located under the link corridor between the Old and New buildings.

In the Old Building, there is one gas supply located in the boiler plant room at basement level nearest the print room, and one gas supply located in the plant room under Spanish Ambassador's. Each of these supplies has its own revenue meter and MPRN.

Beaufort Suite also has its own gas supply with the revenue meter located within the boiler plant room.

Monthly meter reading records have been provided for all meters; no half hourly Automatic Meter Reading (AMR) data has been provided. The meters details are as follows:

Utility	Building	MPRN	Meter Serial Number
Gas	New Building	18110301	75158923
Gas	Old Building	18109406	9311555
Gas	Spanish Ambassador's	18109709	M040K0435814D6
Gas	Beaufort Suite	18109507	MK016K0073816D6

Table 5: Gas meter details

The current gas supplier has not been confirmed but based on total charges provided for the financial year 2022/23, we have inferred the following average rates, which are assumed to include standing charges and Climate Change Levy.

Building	Unit rate p/kWh
New Building	11.9
Old Building	12.4
Spanish Ambassador's	12.6

Table 6: Gas cost details

3.3.2 Monthly consumption profile – New Building

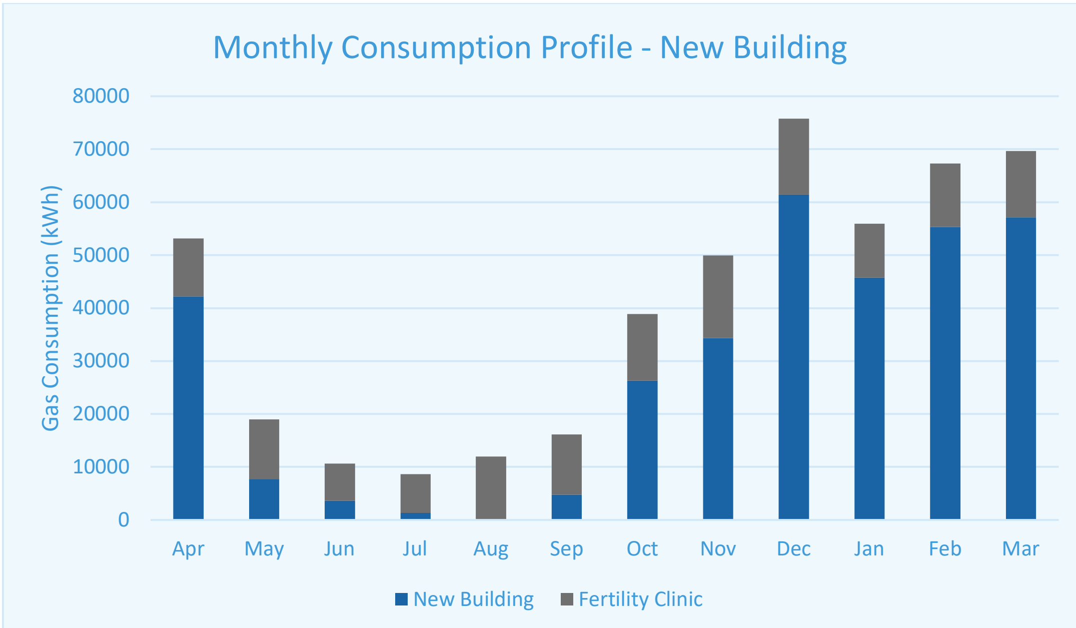


Figure 6: Monthly Gas Consumption – New Building

Manual readings for the fertility clinic gas sub-meter, located in the New Building Level 4 plant room, were provided for April 2022 to June 2023 but missing January to March 2023. We have assumed that the readings were taken at the beginning of each month. The consumption in January to March 2023 are estimated, based on the proportions of consumptions in the previous months.

Figure 6 shows the monthly gas consumption profile for the New Building, including the fertility clinic boiler readings. The profile displays an expected seasonal trend for the building. Gas is used for the boilers to provide space heating only, with the exception of the small boiler providing heating and hot water to the fertility clinic, which is out of scope of this study and accounts for almost all gas consumption from June to August inclusive.

3.3.3 Monthly consumption profile – Old Building

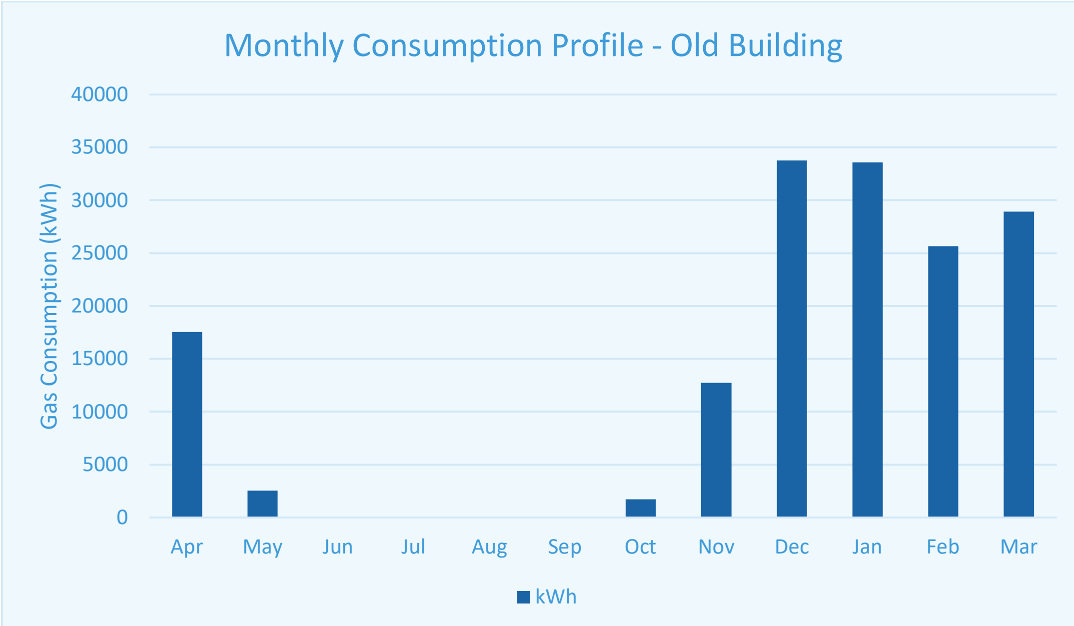


Figure 7: Monthly Gas Consumption – Old Building

The profile displays a seasonal trend by the Old Building with no gas demand in summer. Gas is used for the boilers to provide space heating only so no gas use would be expected in the summer.

3.3.4 Monthly consumption profile – Ingram House/Spanish Ambassador's

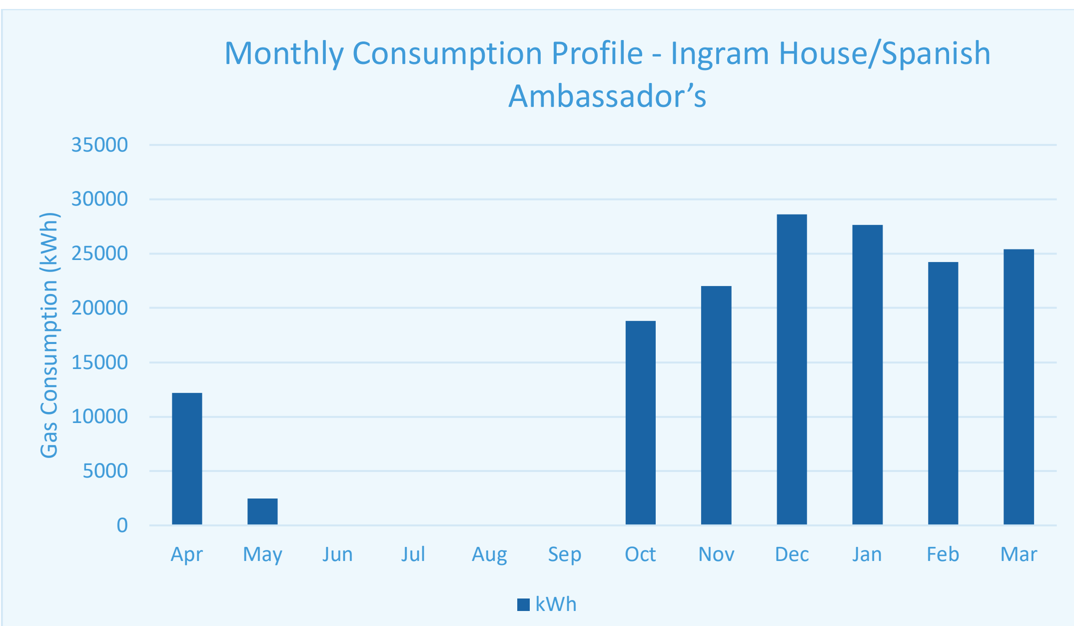


Figure 8: Monthly Gas Consumption – Ingram House/Spanish Ambassador's

The profile displays a seasonal trend for the Ingram House and Spanish Ambassador's with no gas demand in summer. Again, gas is used by the boilers to provide space heating only, so no gas use would be expected in the summer.

3.3.5 Monthly consumption profile – Beaufort Suite

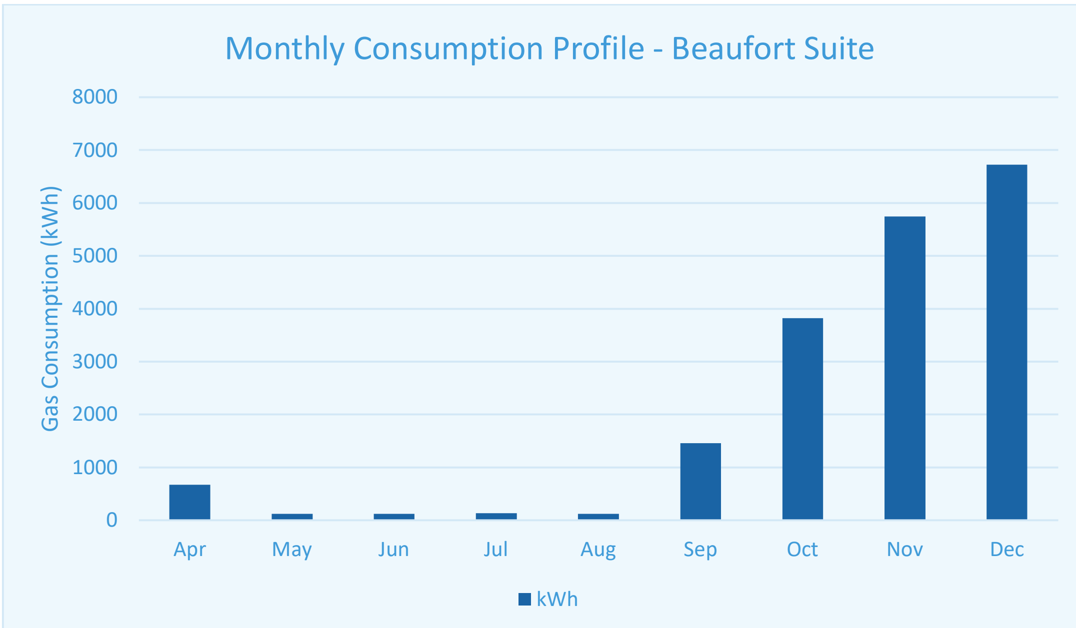


Figure 9: Monthly Gas Consumption – Beaufort Suite

Manual readings for Beaufort Suite were provided from April to December 2022. We have assumed that the readings were taken at the beginning of each month rather than the end.

The profile displays an expected seasonal trend for the building, with very small gas demands in summer and an increase starting from September and continuing through winter. As there is no DHW or catering on gas, there could be some control issues with the boiler. The consumption is variable and subject to the number of functions since this building is used exclusively for private hire functions.

3.3.6 Half Hourly (HH) Data

There is no half hourly gas consumption data available for this site.

3.3.7 Gas regression analysis

Concept have access to total historical gas consumption data for a contiguous period of 12 months, with which we have undertaken a regression analysis, whereby gas consumption is compared with Heating Degree Days (HDD).

HDD are a measure of both the severity and duration of cold periods of weather. One degree day represents a temperature of 1°C below the base temperature, sustained for a period of 24 hours. An

HDD data set for Stansted Airport and a default base temperature of 15.5°C has been selected. It is noted that the actual building base temperatures may vary.

Plotting the gas consumption directly against the heating degree days gives an indication of the dependence of gas use on weather. The slope of the regression line gives an indication of impact of weather on the rate of gas use. The spread of the points about the line (and the R^2 value) give an indication of dependence of gas use on weather. An R^2 value of one would indicate that the gas use is strongly dependent on the number of heating degree days, a value of zero would suggest that the two variables are independent. This analysis is presented in Figure 10.

The R^2 value of approximately 0.94 indicates a strong relationship with degree days with no significant outliers. There appears to be a different correlation below ca. 85 HDD, which corresponds the period May to October over the summer when the main boiler plant was turned off. The correlation at this point relates to the gas consumption of the small gas boiler serving the fertility clinic. Excluding these figures still gives an R^2 value of approximately 0.90.

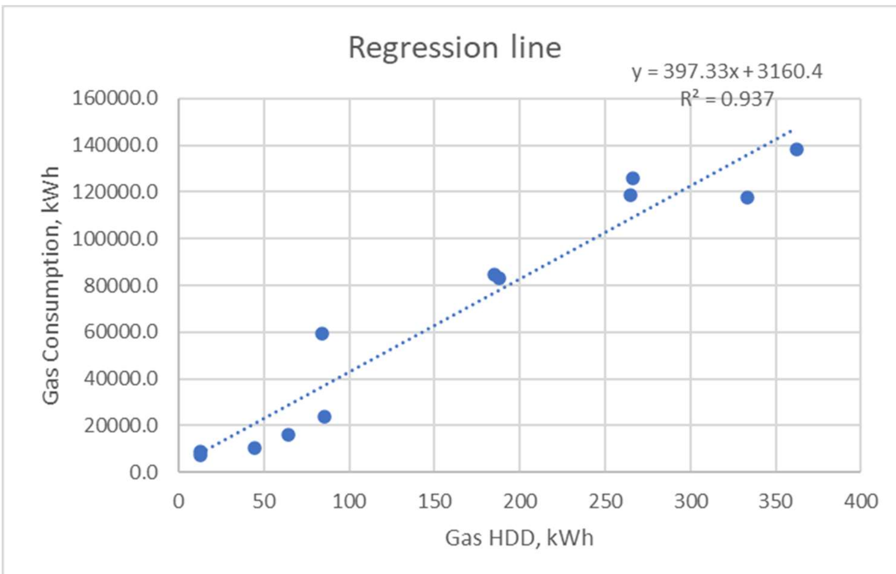


Figure 10: Gas regression analysis

3.4 Sub-metering

It should be noted that the electricity consumption presented in Table 2 is based on the main revenue meter for the New and Old buildings, and the gas consumption is based on the main meter for the New Building. Therefore, the consumption includes leased areas which are outside the operational control of the Council.

As these areas are outside the scope of this study and as sub-metering data has been provided for the period April 2022 to June 2023, this usage will be subtracted from the baseline consumption for modelling purposes.

Manual readings for the fertility clinic, probation services, and NHS have been provided for April to December 2022. We have assumed that the readings provided were taken at the beginning of each month rather than the end. The consumption in January to March 2023 is estimated based on the apportionment of total consumption indicated by readings in December 2022 and April 2023.

The sub-metering details are as follows:

Utility	Meter	Served Area	Energy (kWh)	Energy (%)
Electricity	Main meter	New Building & Old Building	**547,835**	**100.0**
Electricity	Sub-meter	Fertility Clinic	54,186	9.9
Electricity	Sub-meter	Probation Services	24,399	4.5
Electricity	Sub-meter	NHS	23,849	4.4
Electricity	-	Council occupied areas	445,401	81.3

Table 7: Electricity sub-metering details

Utility	Meter	Served Area	Energy (kWh)	Energy (%)
Gas	Main meter	New Building	**476,118**	**100.0**
Gas	Sub-meter	Fertility Clinic	150,828	31.7
Gas	-	Council occupied areas	325,290	68.3

Table 8: Gas sub-metering details

3.5 Energy consumption comparison with benchmark

The purpose of benchmarking is to sense-check the quality of the energy data provided for the audit reference year in terms of energy performance indicator. Benchmarking also gives an indication of the performance of the building compared with other similar properties.

This energy audit uses a benchmark based on the specific energy consumption per square metre (m^2) of the total internal floor area of the site.

The benchmarks selected for this site are taken from CIBSE TM46 benchmarks for 'General office' and have been normalised for occupancy hours and heating degree days in accordance with TM46 guidance. Actual occupancy hours are ca. 2080 hours per annum, compared with the benchmark of 2040 hours per annum. Heating degree days in the consumption year assessed were 1903, compared with the benchmark reference value of 1709.

ELECTRICAL BENCHMARK PERFORMANCE		
Benchmark (kWh/m^2)	**Actual Consumption per floor area (kWh/m^2)**	**Comments**
95.6	78.6	Electricity consumption is lower than the benchmark value. Lighting is mostly from efficient LED and T5 fittings. Some areas of the site are used for private hire functions only and are not frequently used.

Table 9: Electrical benchmark performance

GAS BENCHMARK PERFORMANCE		
Benchmark (kWh/m^2)	**Actual Consumption per floor area (kWh/m^2)**	**Comments**
159.8	114.3	Fossil fuel consumption is lower than the benchmark. It is noted that the site does not have heat sub-meter data for NHS and Probation services, and heating plant is centralised. The consumption would be lower after subtracting the consumptions of NHS and Probation services.

Table 10: Fossil fuel benchmark performance

4 Building Fabric – New Building

4.1 Overview

The New Building was constructed in 1987; it is a brick and block cavity wall construction with a pitched roof and metal framed single glazing throughout. Approximate U-values have been calculated based on observed construction using the BR443 methodology.

4.2 Walls

The walls of the New Building are mostly brick and block construction comprising 140mm internal blockwork, 50mm cavity and 105mm brick exterior. It is suspected that the cavity is filled with insulation.

Based on the above information we have calculated an average U-value of 0.6 W/m^{2}K.

Figure 11: A view of the external walls

4.3 Floor

The floor is believed to be an uninsulated concrete slab.

Based on the above information we have calculated an average U-value of 0.3 W/m^{2}K.

4.4 Roof

The roofs of the New Building are pitched roofs with insulation at rafter level. The insulation is estimated to be 90mm mineral wool.

Based on the above information we have calculated an average U-value of 0.44 W/m^{2}K.

4.5 Glazing

The New Building has single glazing throughout with 4mm glass panes. The windows are metal framed and openable.

We have calculated an average U-value of 5.2 W/m^2K for all glazing.

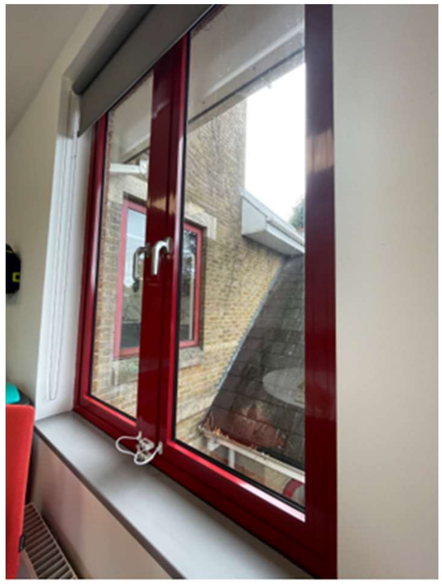


Figure 12: A typical single glazed window

5 Building Fabric – Old Building

5.1 Overview

The Old Building comprises several 19th-century constructions; it is generally a solid brick wall construction with a pitched roof and timber-framed, single glazed box sash windows. The building is listed. Approximate U-values have been calculated based on observed construction using the BR443 methodology.

5.2 Walls

The walls of the Old uilding were measured to be ca. 380mm thick and are of solid brick construction.

Based on the above information we have calculated an average U-value of 1.49 W/m^2K.

Figure 13: A view of the external walls

5.3 Floor

The floor is believed to be an uninsulated concrete slab, but there are large unheated basement areas so some heated areas are not in direct contact with the ground.

Based on the above information we have calculated an average U-value of 0.51 W/m^2K.

5.4 Roof

The roofs of the Old Building are pitched roofs with loft cavities but were not accessed during the visit. It was indicated that there is some loft insulation, but the level was not clear.

Based on the above information we have assumed 90mm of mineral wool insulation at rafter level and calculated an average U-value of 0.44 W/m^2K.

5.5 Glazing

The Old Building has 4mm single glazing throughout. The windows are mostly timber-framed box sash windows which are in poor condition. Air infiltration through these windows is expected to be high in places, though in some instances casements had been painted shut or otherwise sealed.

We have calculated an average U-value of 4.5 W/m^2K for all glazing. It is noted that this is lower than the metal framed windows in the New Building, despite the age of Old Building windows. This is due to the frame material and smaller window dimensions observed, though as noted, air infiltration through windows in this area are likely to exceed those in the main building.

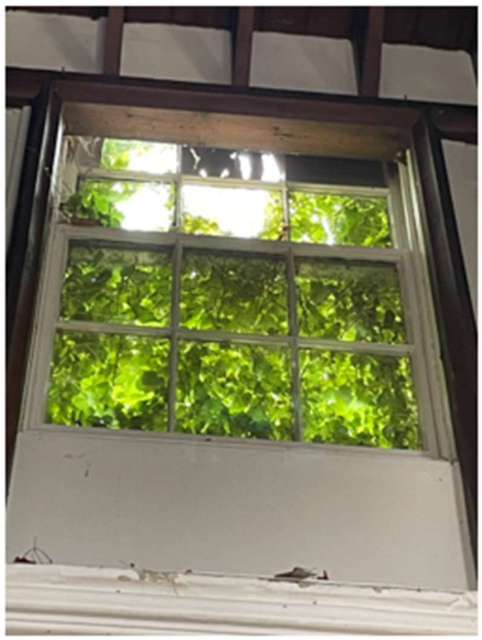


Figure 14: A typical wooden box sash window

6 Building Fabric – Beaufort Suite

6.1 Overview

The Beaufort Suite is a 19th-century building; It is a solid brick wall construction with a pitched roof and wooden box sash windows with single glazing throughout. Approximate U-values have been calculated based on observed construction using the BR443 methodology.

6.2 Walls

The walls of the Beaufort Suite are solid brick walls, with ca. 380mm thickness.

Based on the above information we have calculated an average U-value of 1.49 W/m^{2}K.

Figure 15: A view of the external walls

6.3 Floor

The floor is believed to be an uninsulated concrete slab.

Based on the above information we have calculated an average U-value of 0.55 W/m^{2}K.

6.4 Roof

The roofs are pitched roofs with loft cavities but were not accessed during the visit. It was indicated that there is some loft insulation, but the level was not clear.

Based on the above information we have assumed 90mm of mineral wool insulation at rafter level and calculated an average U-value of 0.44 W/m^{2}K.

6.5 Glazing

The Beaufort Suite has 4mm single glazing throughout. The windows are mostly metal framed ‘crittall’ style windows, which are in reasonable condition for their age.

We have calculated an average U-value of 6.0 W/m^{2}K for all glazing.

Figure 16: A typical wooden box sash window

7 Building Fabric – Print Room

7.1 Overview

The Print room is believed to be a late 19th century or early 20th century construction; it is a solid brick wall construction with a pitched roof and metal framed, single glazed windows throughout. Approximate U-values have been calculated based on observed construction using the BR443 methodology.

7.2 Walls

The walls of the Print room are of solid brick construction, with ca. 380mm thickness.

Based on the above information we have calculated an average U-value of 1.49 W/m^{2}K.

Figure 17: A view of the external walls

7.3 Floor

The floor is believed to be an uninsulated concrete slab.

Based on the above information we have calculated an average U-value of 0.54 W/m^{2}K.

7.4 Roof

The roofs are pitched roofs with no loft cavity. It was assumed that there is some insulation at the rafter level, but the level was not clear.

Based on the above information we have assumed 50mm of mineral wool insulation at rafter level and calculated an average U-value of 0.7 W/m^{2}K.

7.5 Glazing

The Print room has 4mm single glazing throughout. These are all metal framed ‘crittall’ style windows which are in reasonable condition for their age.

We have calculated an average U-value of 6.0 W/m^2K for all glazing.

Figure 18: A typical metal frame window

8 Building services – New Building

8.1 Overview

Space heating to Council operated areas is provided by both 6no. gas fired boilers, via radiators and AHUs, and by electric heating coils in ventilation supply ductwork.

DHW is provided by electric cylinders.

Level 2 Council offices and the Council chamber on level 1 are mechanically ventilated by AHUs, while Level 1 and level 3 are naturally ventilated by openable windows.

There is a small number of split Air Conditioning (A/C) units in the New Building only. for space cooling in specific areas.

Lighting is mostly provided by LED panels.

8.2 Space heating

The New Building has 6no. Hamworthy 'UR 430-Auto' gas fired boilers located in the plant room on level 4. Each boiler has a nominal heat output of 95.8kW. The boilers are floor standing, non-condensing models and manufactured in around 1985, and are therefore considered end-of-life with respect to the relevant CIBSE Guide M economic life of 20 years.

Also, there is a relatively new wall hung condensing Vaillant 'ecoTEC plus' gas which has a nominal heat output of 63.7kW and was manufactured in 2015. This boiler serves the leased fertility clinic, who have operational control of the plant. The gas supply to this plant is sub-metered and out of scope of this study.

Figure 19: Floor standing gas boilers (left) and wall hung gas boiler (right)

The main boiler plant supplies 2no. secondary circuits to serve AHUs and radiators. The AHUs circuit is Constant Temperature (CT) circuit and the radiators circuit is Variable Temperature (VT) circuit.

Pump ratings within the plant room are as follows:

- Primary pumps – 2no. 750W fixed speed pump motors
- VT circuit – 2no. 2.2kW fixed speed pump motors
- CT circuit – 2no. 2.2kW fixed speed pump motors

Plant room pipework insulation is generally in poor condition. Parts of the pipe are uninsulated and most of the valves have no insulation.

PRIMARY HEAT SOURCE					
Type	**Make**	**Model**	**Rated Input**	**Rated Thermal Output**	**Comments**
6no. gas fired boiler	Hamworthy	UR 430-Auto	124.8kW	95.8kW	Floor standing, non-condensing End-of-life
4no. electric reheat coils	Neatafan	Unknown	3kW	3kW	Local reheat of AHUs

Table 11: Primary Boiler Plant

Space heating is delivered via radiators with thermostatic radiator valves (TRVs) although these do not appear to be sufficiently sized to heat the space.

Additional heat is provided to the AHUs for fresh air tempering but local reheat is provided by 3kW electric duct heaters at supply air points within the occupied space, which supplements the heating from the radiators.

A new supply and extract AHU has been installed to serve level 2 Council offices but has not yet been fully commissioned and was off at the time of the survey. There is an AHU serving the Council chamber on level 1, which is the primary heat source in this area but appears to be significantly oversized.

Table 12: One of the local electric reheater batteries in a Level 2 ventilation riser cupboard

8.3 Domestic Hot Water

DHW to the New Building is provided by a 210 litre electric calorifier in the plant room serving toilets. It is equipped with a 3kW immersion heater.

There is a 200 litre DHW calorifier serving the Ground floor private clinic. It is equipped with a 3kW immersion heater but is served by the standalone wall mounted gas boiler serving the clinic, and is out of scope of this report.

Electric point of use water heaters are provided for kitchenettes within the council offices.

Figure 20: Electric calorifiers

DOMESTIC HOT WATER					
Type	**Make**	**Model**	**Rated Input**	**Rated Thermal Output**	**Comments**
1no. electric calorifier	JAB	Duplex unvented cylinder	3kW	3kW	200 litres Manufactured in 2020
1no. point of use heater	Heatrae Sadia	Streamline	3kW	3kW	7 litres
1no. point of use heater	Ariston	Unknown	3kW	3kW	9 litres Serves facilities office
3no. point of use heater	Unknown	Unknown	3kW	3kW	Serves Council occupied areas

Table 13: Domestic Hot Water Plant

8.4 Ventilation

Level 2 Council offices and the Council Chamber on level 1 (ground floor) are mechanically ventilated by AHUs.

Level 1 and level 3 are naturally ventilated by openable windows.

The AHU for level 2 is new and awaiting final commissioning, and was therefore switched off during the survey. It comprises of separate supply and extract sections and is equipped with a run around coil between separate two sections for heat recovery. The fans are direct driven with variable speed inverter drives.

The AHU for the Council Chamber is located in the plant room next to the facilities office and it appears to be significantly oversized. The AHU fan casing could not be accessed to establish fan type and ratings but the unit is believed to be end of life and contains belt driven fans.

There are some additional extract fans for toilets, kitchen and 'laboratory', all located in the main level 4 plant room but only the toilet extracts are in use.

Figure 21: The New AHU 1 supply section serving Level 2 council offices

AIR HANDLING UNITS					
REFERENCE	**Type**	**Nominal Power (kW)**	**Serving**	**Control**	**Comments**
AHU 01	Supply	5.5	Level 2 Council offices	VSD	Flow rate: 10.8 m^3/h
	Extract	4			
AHU 02	Supply	Unknown	Level 1 Council chamber	Fixed speed	End of life
TE 1	Extract	Unknown	Toilet	Fixed speed	
TE 2	Extract	Unknown	Toilet	Fixed speed	
KE 1	Extract	Unknown	Kitchen	Fixed speed	Not in use

AIR HANDLING UNITS					
REFERENCE	Type	Nominal Power (kW)	Serving	Control	Comments
KE 2	Extract	Unknown	Kitchen	Fixed speed	Not in use
LE 1	Extract	Unknown	Laboratory	Fixed speed	Not in use
LE 2	Extract	Unknown	Laboratory	Fixed speed	Not in use

Table 14: Air Handling and Ventilation plant

8.5 Space Cooling

There are a number of split A/C units at the front (car park side) of the building outside the facilities office. These were installed between 2012 and 2022 and serve the main comms room (3 units) 'NOMS Patch room' (2 units) and Facilities office (1 unit).

Figure 22: Indoor units

SPACE COOLING					
REFERENCE	Type	Nominal Electrical Power (kW)	Make	Model	Serving
2no. A/C units	Split A/C	1.77	Mitsubishi	PUHZ-ZRP71VHA	Main comms room
1no. A/C units	Split A/C	3.1	Mitsubishi	PUZ-ZM100VKA	Main comms room
2no. A/C units	Split A/C	1.66	Daikin	RZQG71L7V1B	'NOMS Patch room'
1no. A/C units	Split A/C	3.42	Samsung	AC100RXADKG/EU	Facilities office

Table 15: Air Handling and Ventilation plant

8.6 Lighting

8.6.1 Internal Lighting

Lighting to the New Building is LED throughout. The LED lamps are mostly square panels with Passive Infrared (PIR) motion sensors.

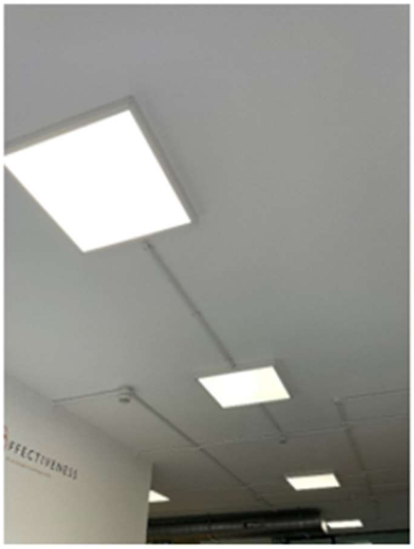


Figure 23: LED panels

8.6.2 External Lighting

There are car park lighting and building mounted external bulkhead lighting. The lighting have timeclocks located in electric cupboard in facilities office and also photocell control.

Figure 24: Car park lighting

8.7 Building Management System

There is a BMS controlling the new AHU only, which is accessible only via a laptop with the appropriate software. Screen grabs of the graphics have been provided to Concept after the site visit.

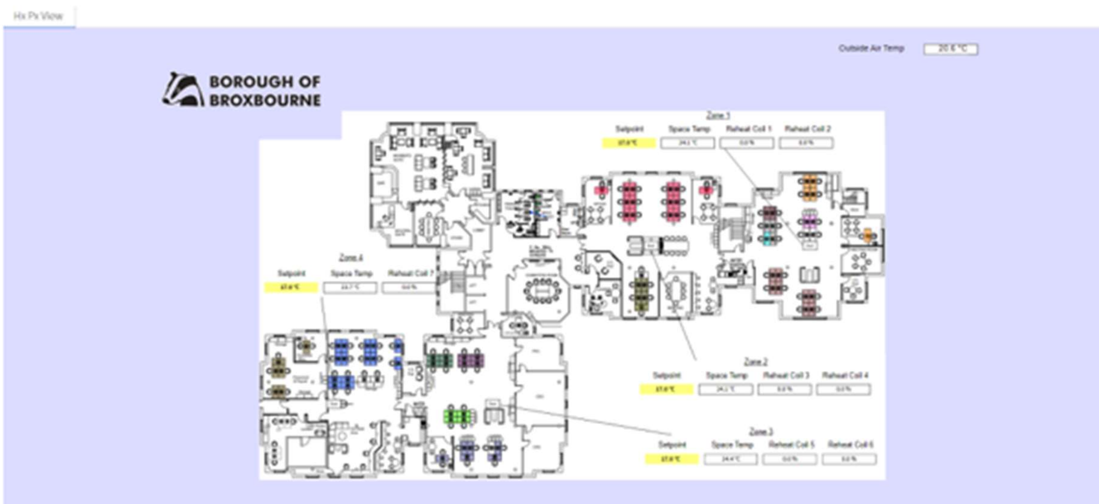


Figure 25: BMS interface

The AHU return temperature setpoint was set to 17°C, frost protection temperature setpoint was set to 10°C, supply and extract fan speed setpoints were set to 75% and 80%.

The AHU operational hours were set to 06:00hrs to 18:00hrs Mondays to Fridays, and off weekends.

The boiler operational hours were controlled by a local timeclock in the level 4 plant room, which was set as follows:

Day	Operational Hours
LTHW	
Tuesday – Thursday	07:00hrs to 18:00hrs 18:20hrs to 22:30hrs
Friday	07:00hrs to 18:00hrs 18:10hrs to 18:20hrs
Saturday – Monday	06:20hrs to 06:30hrs 11:50hrs to 12:00hrs 16:20hrs to 16:30hrs
DHW	
Monday – Friday	06:30hrs to 08:30hrs 12:00hrs to 13:00hrs 16:30hrs to 22:30hrs
Saturday – Sunday	06:30hrs to 09:30hrs 12:00hrs to 13:00hrs 16:30hrs to 23:00hrs

Table 16: Boilers operational hours

8.8 Small Power

There estimated to be ca. 80no. laptop docking workstations with monitors only in this building.

The small power loads in kitchenettes include microwave, kettle, washing machine, dishwasher and fridge. The equipment in the private clinics is out of scope of this survey.

Figure 26: Workstation (left) and kitchenette (right)

8.9 Catering

There is no commercial catering equipment in the New Building.

8.10 IT loads

There is a main comms room but it was not visited.

A battery UPS is located in the facilities office. The loading of the UPS was also not obtained during the survey.

The main comms room is served by 3no. A/C units with a total rated cooling capacity of ca. 24kW, which the most recent TM44 deems to be an appropriate size based on computer room loads, allowing for appropriate redundancy. This is therefore likely to account for a significant proportion of the baseload electricity demand.

Figure 27: UPS

8.11 On-site generation and renewable energy sources

There is no on-site generation and renewable energy sources in the New Building.

9 Building services – Old Building

9.1 Overview

Space heating is provided by gas fired boilers via radiators.

DHW is provided by electric cylinders.

The building is naturally ventilated through openable windows.

There is no space cooling plant in the Old Building.

Lighting is mostly provided by T5 fittings with a few LED fittings.

9.2 Space heating

There are 2no. main boiler plant rooms in the Old Buildings.

The plant room at the east end of the building at basement level serves most of the building. It has 3no. Hamworthy 'Warmwell 95 Auto' gas fired boilers. Each boiler has a nominal heat output of 93 kW. The boilers are floor standing, condensing models, manufactured in 2004. CIBSE Guide M suggests an economic life for floor standing boilers of 20 years and therefore these boilers considered 'end-of-life'.

There is a basement level plant room under Spanish Ambassador's House, which serves the Spanish Ambassador's House and Ingram House. Huntingdon Suite is potentially served by this plant room but there are no schematics to confirm. The plant room contains 3no. Hamworthy 'Purewell 70 Auto' gas fired boilers. Each boiler has a nominal heat output of 70 kW. The boilers are floor standing, non-condensing models. The exact year of manufacture was not determined but are believed also to be end of life.

Figure 28: Gas boilers at the east end of the Old Building (left) and the basement plant room at Spanish Ambassadors House (right)

Each set of boilers serve one CT secondary circuit, which splits into sub-circuits with zone valves.

Known pump ratings within the plant room are as follows:

- Primary pumps at basement of the east section – 2no. 1.4 kW fixed speed pump motors
- CT circuit at basement of the east section – 2no. 774 W fixed speed pump motors
- CT circuit at Spanish Ambassador's – 2no. 750 W fixed speed pump motors

The Old Building plant room pipework insulation is generally in good condition, while some valves have no insulation or insulation removed.

The Spanish Ambassador's plant room pipework insulation is in poor condition, some insulation is damaged and valves insulation is missing.

PRIMARY HEAT SOURCE					
Type	**Make**	**Model**	**Rated Input**	**Rated Thermal Output**	**Comments**
3no. gas fired boiler	Hamworthy	Warmwell 95 Auto	101 kW	93 kW	Floor standing, condensing End-of-life
3no. gas fired boiler	Hamworthy	Purewell 70 Auto	79.6 kW	70 kW	Floor standing, non-condensing End-of-life

Table 17: Primary Boiler Plant

Space heating is delivered via radiators with TRVs.

9.3 Domestic Hot Water

DHW to the Old Building is provided by electric cylinders. There is one in the basement of the east section serving kitchenettes on each floor and toilets, and one in Ingram house serving Ingram, believed to serve Ingram, Spanish Ambassador's, and possibly the kitchen in the Huntingdon Suite. Each cylinder is equipped with a ca. 3 kW immersion heater.

There is an electric shower in Ingram House.

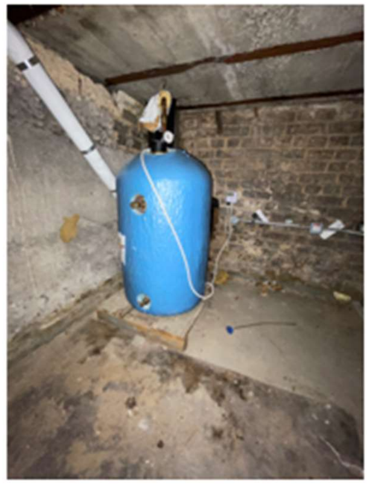


Figure 29: Electric cylinder

DOMESTIC HOT WATER					
Type	**Make**	**Model**	**Rated Input**	**Rated Thermal Output**	**Comments**
1no. electric cylinder	Unknown	Unknown	3 kW	3 kW	Serves kitchenettes on each floor and toilets
1no. electric calorifier	Unknown	Unknown	3 kW	3 kW	Serves Ingram and Spanish Ambassadors

Table 18: Domestic Hot Water Plant

9.4 Ventilation

The Old Building is mostly naturally ventilated. There is an audible fan underneath the Octagonal Suite reportedly running continuously but this was not accessed.

9.5 Space Cooling

There is no space cooling equipment in the Old Building

9.6 Lighting

9.6.1 Internal Lighting

Lighting to the Old Building is mostly T5 with a few LEDs, which is manually controlled.

Figure 30: T5 fitting

9.7 Building Management System

There is a BMS controlling the heating system of the plant room at the east end of the building at basement level, which can be controlled by the BMS panel in the plant room or accessed via a laptop with the appropriate software. Screen grabs of the graphics have been provided to Concept after the site visit.

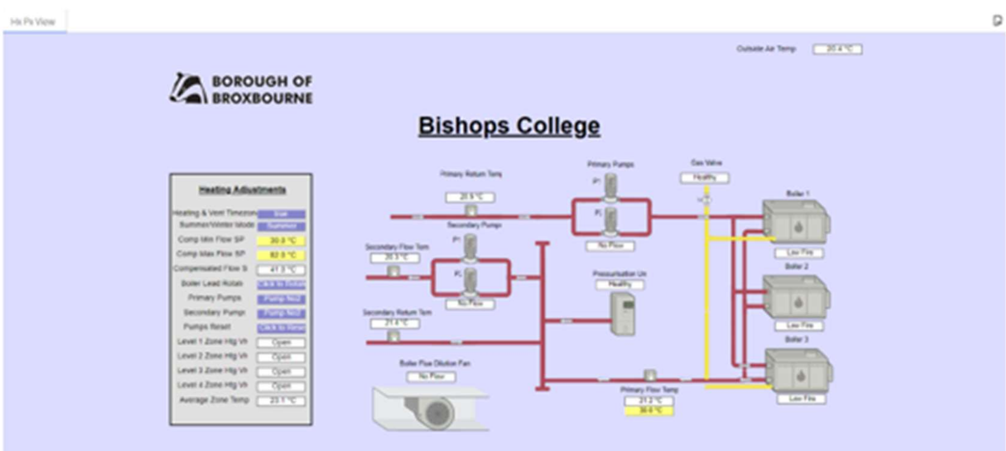


Figure 31: BMS interface

The LTHW minimum and maximum temperature setpoints were set to 30°C and 82°C. The room temperature setpoint was set to 22°C.

The boiler plant operational hours were set to 06:30hrs to 17:00hrs Mondays to Fridays, and 09:00hrs to 14:00hrs on weekends.

9.8 Small Power

There are 3no. kitchens on first floor and second floor containing air fryers, kettles, toasters, and undercounter fridges.

Figure 32: kitchenette

Concept did not access leased areas in the building and it is expected that these areas additionally contain typical office equipment including laptops or PCs, printers and small communications cabinets.

9.9 Catering

There is some catering equipment in the Old Building kitchen including commercial fridge and freezer, water heater, 6 rings electric hobs, and hot food cabinet. It is unclear how often this kitchen is used.

Figure 33: Kitchen

9.10 IT loads

No significant centralised IT loads were identified in the Old Building.

9.11 On-site generation and renewable energy sources

There is no on-site generation and renewable energy sources in the Old Building.

10 Building services – Beaufort Suite

10.1 Overview

Space heating is provided by a gas fired boiler via fan convector heaters.

DHW is provided by electric point of use heaters.

The building is naturally ventilated through openable windows.

There is no space cooling plant in the Beaufort Suite.

Lighting is mostly provided by LED fittings.

10.2 Space heating

There is a plant room in the Beaufort Suite containing 1no. Stelrad Ideal 'Concord CX' gas fired boiler. The boiler has a nominal heat output of 80.6 kW. The boilers are floor standing, non-condensing models. The manufacturer year is not clear but it is believed to be in excess of 20 years. The condition of the boiler appears to be poor and it is considered end of life.

Figure 34: Gas boiler

Space heating is delivered via fan convectors served by the boiler.

The plant room pipework is mostly uninsulated.

PRIMARY HEAT SOURCE					
Type	**Make**	**Model**	**Rated Input**	**Rated Thermal Output**	**Comments**
1no. gas fired boiler	Stelrad Ideal	Concord CX	100.7 kW	80.6 kW	Floor standing, non-condensing End-of-life

Table 19: Primary Boiler Plant

10.3 Domestic Hot Water

DHW to the Beaufort Suite is provided by electric point of use heaters, which were not inspected during the survey.

10.4 Ventilation

The Beaufort Suite is naturally ventilated only.

10.5 Space Cooling

There is no space cooling equipment in the Beaufort Suite

10.6 Lighting

10.6.1 Internal Lighting

Lighting to the Beaufort Suite is mostly LED, with some pendant fittings for which the lamp type could not be confirmed. Lighting is manually controlled.

Figure 35: LEDs

10.7 Building Management System

There is no BMS in the Beaufort Suite.

10.8 Small Power

The small power loads in the kitchenette are limited and include a water boiler and fridge. Other small power loads will include equipment brought by occupants hiring the hall, such as audio equipment, however none was present during the survey.

Figure 36: The kitchenette in Beaufort Suite

10.9 Catering

There is no commercial catering equipment in the Beaufort Suite.

10.10 IT loads

There were no observed IT loads in the Beaufort Suite.

10.11 On-site generation and renewable energy sources

There is no on-site generation and renewable energy sources in the Beaufort Suite.

11 Building services – Print Room

11.1 Overview

Space heating is provided by electric wall mounted electric radiant tube heaters. There is no DHW plant present.

The building is naturally ventilated through openable windows and there is no space cooling plant.

Lighting is mostly provided by T5 fluorescent fittings.

11.2 Space heating

Space heating for the Print room is provided by electric wall mounted radiant tube heaters.

There were also cast-iron radiators and suspended gas-fired radiant heaters present but these are reportedly no longer in use.

Figure 37: Wall mounted radiant tube heaters

11.3 Domestic Hot Water

There is no DHW plant in the Print Room.

11.4 Ventilation

The Print Room is naturally ventilated.

11.5 Space Cooling

There is no space cooling plant in the Print Room.

11.6 Lighting

11.6.1 Internal Lighting

Lighting to the Print room is mostly provided by T5 fittings, which appears to be manually controlled.

Figure 38: T5 fluorescent fittings

11.7 Building Management System

There is no BMS in the Print Room. Radiant heating is believed to be operated manually.

11.8 Small Power

There is a small amount of commercial printing equipment in the Print Room, which is expected to be in regular use throughout normal occupancy.

11.9 Catering

There is no catering equipment in the Print Room.

11.10 IT loads

There are no significant centralised IT loads in the Print Room.

11.11 On-site generation and renewable energy sources

There is no on-site generation and renewable energy sources in the Print Room.

12 Energy Modelling and Usage analysis

We have used RETScreen software to create 'bulk' energy model of the buildings.

RETScreen is a software package developed by the Canadian government for project feasibility analysis of energy efficiency and renewable energy technologies. The software calculates annual average energy flows for a range of HVAC systems and specific load types.

Baseline models have been created using drawings and site details collected during our site visits. This provides a reasonable estimate of the building operation from which to calculate potential savings from a range of decarbonisation measures.

12.1 Details of assumptions used in the base model

All building fabric elements have been modelled as per Section 4 - 7 of this report.

12.1.1 Air permeability

Air permeability testing records have not been provided or located on site and air permeability has therefore been estimated within RETScreen for each treated space based on building age.

Based on the building fabric conditions and age of the buildings, we have applied a default 'medium' setting for air permeability for walls and 'leaky' for windows for the New Building and 'leaky' setting for walls and windows for the other buildings within the software.

The unknown air permeability is a large source of uncertainty within the energy model as it is a significant constituent of the space heating load. In order to improve the accuracy of the energy model, air permeability testing could be undertaken to assess any degradation in performance of elements such as door and window seals; however, it is understood that this may be impractical due to the building use.

It should be noted that air permeability refers to uncontrolled and undesired infiltration. Mechanical ventilation is modelled separately.

12.1.2 Building services systems

Building services systems have been modelled as per the plant descriptions given in Section 8 - 11 of this report.

12.1.3 Weather data

The RETScreen model uses inbuilt climate database files selected by the user based on the site location. We have selected the nearest weather file location, in London Weather Centre, which incorporates a mix of ground data and NASA global satellite climate data.

12.1.4 Energy cost

We have assumed a rate of 11.9p/kWh for gas and 32.8p/kWh for electricity based on known rates given in Section 3.

12.2 Modelled Baseline Carbon Footprint

Concept have used the output from the RETScreen energy model (electricity and gas import) to derive the baseline carbon footprint of the site.

The footprint is based on the 2022 Greenhouse Gas reporting emissions factors as published by HM Government [2].

Building	Emissions Source	Emission Scope	Baseline Consumption (kWh)	Emissions Factor (CO_2e/kWh)	Baseline Emissions (tCO_2e)
New Building	Grid Gas	Scope 1	325,380	0.18254	59.4
	Grid Electricity	Scope 2	420,923	0.19338	81.4
Old Building	Grid Gas	Scope 1	156,215	0.18254	28.5
	Grid Electricity	Scope 2	72,688	0.19338	14.1
Ingram House/Spanish Ambassador's	Grid Gas	Scope 1	161,493	0.18254	29.5
	Grid Electricity	Scope 2	11,854	0.19338	2.3
Beaufort Suite	Grid Gas	Scope 1	30,525	0.18254	5.6
	Grid Electricity	Scope 2	6,282	0.19338	1.2
Print room	Grid Electricity	Scope 2	31,653	0.19338	6.1
Total Emissions					**228.0**

Electricity consumption in the baseline model (88.4 kWh/m^2 per annum) is very similar to actual metered consumption (88.4 kWh/m^2 per annum).

The consumption of gas in the baseline model (116.4 kWh/m^2 per annum) is also similar to actual metered consumption (116.4 kWh/m^2 per annum).

For the purposes of this report the emissions scopes are as follows:

- Scope 1 emissions relate to emissions from the combustion of fuels on site. Scope 1 would ordinarily include other fuel use, such as vehicle fuel emissions by owned assets. However, the scope of this study has been limited primarily to building services.
- Scope 2 emissions presently relate to the production of electricity, however in future these could include emissions from district heating.

[2] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2022

Note that we have not included any scope 3 emissions associated with transmission and distribution of these energy supplies.

12.3 Peak Heat Loss

We have calculated approximate 'steady state' peak heat losses using the Salix Peak Building Heat Loss Calculation Tool, based on a design outside air temperature of -3°C and internal setpoint temperatures of 20°C, the calculated peak heat losses are shown as follows:

Building	Calculated Peak Heat Loss	Existing Boiler Size
New Building	573kW	587kW
Old Building	310kW	279kW
Ingram House/Spanish Ambassador's	84kW	210kW
Beaufort Suite	70kW	80.6kW
Print Room	41kW	Unknown

Table 20: Peak heat loss

The calculated peak heat loss of the New Building is slightly lower than the size of the existing boiler. However, this could be further reduced to ca. 561kW as ca.12kW heating demands are met by electric AHU reheat coils. It is noted that this calculation includes the heat loss for the NHS and Probation services, as heating for these areas is centralized.

In Ingram House and the Spanish Ambassador's building, the calculated peak heat loss is significantly lower than the capacity of the existing boilers. Given the size of the internal floor areas, it appears that the existing boilers are oversized. This may be to provide spare capacity in the event of failure but given the site use is the same as the rest of the site, this would not be expected.

The calculated peak heat loss of the Old Building is slightly higher than the capacity of the existing boiler. Conversely, the calculated peak heat loss of the Beaufort Suite is lower than the existing boiler capacity. Since the u-values of the building fabric are estimated, there may be minimal differences between the calculated peak heat loss and the existing boiler capacity.

Space heating to the Print room is provided by electric wall mounted radiant tube heaters.

The calculated peak heat losses do not include DHW demands as DHW to the site is fully electric.

13 Site Decarbonisation Options

13.1 Carbon Reduction Hierarchy

Concept believe that any pathway to carbon reduction should follow the hierarchy of:

- Energy saving (through behaviours and controls)
- Energy efficiency (through improvements to the building and equipment)
- Low carbon heat sources
- Renewable generation
- Carbon offsetting

For Bishops College we have identified the measures as shown below.

13.2 Energy Saving

13.2.1 Heating controls

The boiler plant is controlled by timeclock in the New Building and a BMS schedule in the Old Building. We observed that the boilers are active for longer hours than the actual occupancy hours and schedules could be adjusted to match site occupancy to reduce energy consumption.

We have modelled a carbon increase of ca. 1.8 tonnes of CO_2e per year in the New Building and ca. 12.5 tonnes of CO_2e per year in the Old Building for this measure.

13.2.2 Summary of savings for energy saving measures

Table 21 shows the summary of savings for energy efficiency measures.

Measure	Saving, kWh/yr	Saving, £/yr	Saving, tCO_2e/yr
Heating controls (New Building)	9,693	2,200	1.8
Heating controls (Old Building)	68,467	8,148	12.5

Table 21: Summary of savings for energy saving measures

13.3 Energy Efficiency

13.3.1 Replace Chamber AHU belt driven fan with direct drive fan

The New Building Chamber AHU fan is belt driven and could be replaced by a direct drive fan. The belt driven fan could introduce additional losses and require additional maintenance. Utilising direct drive fan with variable speed control would significantly reduce fan energy usage.

Replacement of direct drive fan could also potentially utilise additional variable speed drives to automatically vary fan speed in relation to a given setpoint, such as a pressure, temperature or CO_2 setpoint.

We have assumed the AHU fan power to be one fifth of the AHU for Level 2 Council offices based on the served floor areas and modelled a carbon reduction of ca. 0.4 tonnes of CO_2e per year for this measure.

13.3.2 Plant room pipe and valve insulation

The plant rooms pipe and valve insulation is generally in poor condition.

We estimate that there were approximately 10m of pipework and 30no. valves uninsulated or with insulation damaged. The below saving is estimated based on a heat loss saving of 68W per metre of pipework.

We have modelled a carbon reduction of ca. 0.9 tonnes of CO_2e per year for this measure.

13.3.3 Roof insulation

The roof insulation of both the New Building and Old Buildings is expected to be below current standards. Improving the roof insulation would reduce the building heat loss.

We have assumed that top up insulation could be applied to both buildings but the existing insulation level would need to be confirmed.

We have modelled a carbon reduction of ca. 2.3 tonnes of CO_2e per year in the New Building and ca. 0.2 tonnes of CO_2e per year in the Old Building for this measure.

13.3.4 Glazing

Glazing to the site is all single glazed windows. This is a significant source of heat loss and well below current standards. Replacing with double or triple glazing would reduce the building heat loss and may improve occupant comfort.

This may only be possible to implement in the New Building as the old buildings are listed buildings, and we have modelled savings on this basis. However, it is possible that a suitable secondary glazing or timber-framed double glazing solution could be found for the old buildings given the poor condition of many of the existing frames.

We have modelled a carbon reduction of ca. 5.0 tonnes of CO_2e per year for this measure.

13.3.5 Summary of savings for energy efficiency measures

Table 22 shows the summary of savings for energy efficiency measures.

Measure	Saving, kWh/yr	Saving, £/yr	Saving, tCO_2e/yr
Replace Chamber AHU belt driven fan with direct drive fan	1,931	648	0.4
Plant room pipe and valve insulation	4,740	564	0.9
Roof insulation (New Building)	12,516	1,506	2.3
Roof insulation (Old Building)	1,033	123	0.2
Glazing	27,296	3,940	5.0

Table 22: Summary of savings for energy efficiency measures

13.4 Low Carbon Heat Sources

The majority of the site's heat demand is met by gas boilers and decarbonisation of heat typically requires direct combustion of fossil fuels on site to be removed or minimised. Therefore, heat decarbonisation is likely to involve electrification of heating, with heat pumps typically providing the most efficient solution. The Council also has experience of implementing biomass at other Council sites and this may be an alternative option at Bishops College.

As DHW plant is already electrified and are relatively new, the low carbon heating options would be focused on space heating plant only.

13.4.1 Air Source Heat Pump

Air Source Heat Pumps (ASHP) would typically provide higher efficiency and lower carbon emissions compared to gas fired boilers but the running costs would be slightly higher than a gas boiler system. ASHPs could be installed to provide space heating for both the New Building and the Old Building.

Using ASHPs would increase the grid electricity demand significantly; the current electricity meter and half hourly data both indicate a current peak demand of ca. 148kW. The site may require up to ca. 720kW of additional available supply capacity with heat pumps as the New Building and the Old Building have the same electricity supply, based on the calculated peak heat loss. This is subject to further feasibility discussion with the District Network Operator (DNO).

ASHPs could be in the form of either a central air to water system or multiple air to air systems.

The external ASHP units of either type could be installed in a new ground mounted compound outside the east walls.

13.4.1.1 Air to Water Heat Pump

Air to Water heat pumps (AWHP) transfer heat to water in a conventional heating distribution system. This would be controlled centrally. An AWHP system could be installed to replace the gas fired boilers.

It is likely that a full replacement of the distribution system and AHU heating coils would be required to facilitate reduced flow temperatures for this option. This may be a particular challenge in the Grade 2 listed Old Building, both because of the impact on building aesthetics and because of the size of the emitters that would likely be required to meet peak heat losses with reduced flow temperatures from a typical AWHP. This requires detailed design to identify a suitable solution, which may involve the use of 'high temperature' heat pumps at the cost of slightly reduced efficiency.

We have assumed the Seasonal Coefficient of Performance of AWHP to be 3. We have modelled a carbon reduction of ca. 36.4 tonnes of CO_2e per year in the New Building and ca. 11.4 tonnes of CO_2e per year in the Old Building for this measure.

13.4.1.2 Air to Air Heat Pump

Air to air heat pumps (AAHP) deliver heat energy directly from the refrigerant coil to the building, typically via a series of internal Fan Coil Unit (FCUs). An AAHP system could be installed as a replacement space heating system. The system could consist of a number of individual or multi-split units serving new FCUs to areas not served by AHUs.

However, this option is not feasible for the Old Building as it is a listed building.

We have assumed the Seasonal Coefficient of Performance of an AAHP to be 3. We have modelled a same carbon reduction as AWHPs for the New Building.

13.4.2 Ground Source Heat Pump

Instead of ASHPs, closed loop Ground Source Heat Pumps (GSHPs) could be utilised to provide space heating for the New Building, with multiple borehole collectors installed to a depth of up to ca. 200m.

The feasibility of this option would depend on the grass area adjacent to the New Building, which has an area of ca. 400m^2. Heat pumps could be installed to replace boilers in the existing plant room. It is believed that this option could be implemented to the New Building only according to the grass area.

The soil type in this area is believed to be clay, silt and sand according to BGS Geology of Britain map viewer, therefore we believe an output of ca. 40W/m of ground collector would be achievable. With 200m borehole depth, a total of ca. 70 boreholes would be required to meet the heat demand of the New Building. However, only ca.20 boreholes could be installed in the available grass area giving a heat output of ca. 160kW. The remaining ca. 400kW heating load would be topped up from an AWHP.

As with ASHP, GSHP would require an additional available grid supply capacity of up to ca. 410kW, which is subject to further feasibility with the DNO.

We have assumed the Seasonal Coefficient of Performance of GSHP and AWHP to be 4 and 3. We have modelled a carbon reduction of ca. 37.7 tonnes of CO_2e per year for this measure.

13.4.3 Water Source Heat Pumps

As the site is next to the New River, an open loop Water Source Heat Pumps (WSHP) system could be implemented to meet site heat loads. An open loop WSHP system consists of open pipe from river to a heat exchanger.

This option is dependent on the flow rate of the New River to recover sufficient heat, which is subject to further detailed feasibility. We have assumed that it could be implemented to the New Building only.

Again, WSHP would require an additional available grid supply capacity of up to ca. 413kW, which is subject to further feasibility with the DNO.

However, there would be additional cost for applying for an abstraction license for using the New River as the source.

We have assumed the Seasonal Coefficient of Performance of WSHP to be 4. We have modelled a carbon reduction of ca. 40.1 tonnes of CO_2e per year for this measure.

13.4.4 Direct electric heating

The existing LTHW distribution and radiators could be replaced by wall mounted electric heaters in both the New Building and the Old Building.

Direct electric heating has a higher efficiency than a gas boiler system and as the emissions factor for grid electricity is steadily decreasing, the site's heating would still continue to decarbonise over time.

The New Building would require ca. 188no. 3kW wall mounted electric heaters with ca. 12kW provided by existing 4no. AHU reheat coils; and the Old Building would require ca. 104no. 3kW wall mounted electric heaters.

Using direct electric heating would require an additional available grid supply capacity of up to ca. 720kW as mentioned before. This is subject to further feasibility with the DNO.

The running cost of direct electric heating would be higher than the existing boiler systems and any of the heat pump systems modelled, as electricity cost per unit is higher than for gas and electric heaters have lower efficiency than a heat pump system.

We have modelled a carbon reduction of ca. 7.1 tonnes of CO_2e per year in the New Building and ca. 2.4 tonnes of CO_2e per year in the Old Building for this measure.

13.4.5 Biomass boiler

The gas fired boilers could be replaced by biomass boilers. This would produce lower CO_2 emissions than gas fired boilers as the fuel is renewable. Wood chip or wood pellets are most commonly used as biomass fuel.

As the existing boilers are end of life, biomass boilers could provide greater efficiency than the old boilers. Biomass boilers provide the same flow temperature as gas boilers therefore no change is required to existing distribution systems.

A biomass boiler is most efficient when consistently running at full load, without frequent on/off cycling. We have assumed that half of the site's heating load would be covered by the biomass boiler, with electric boilers topping up as needed. This would need to be designed carefully to ensure efficiency of the biomass system, which may incorporate significant thermal storage capacity.

The New Building would require a 281kW biomass boiler with ca. 280kW top up electric boilers; and the Old Building would require a 155kW biomass boiler with ca. 155kW top up electric boilers.

As the site is near the Churchgate Road, there is access for truck to deliver fuel to the site.

13.4.5.1 New Building

A containerized biomass boiler system could provide an integrated boiler room and fuel store in a container.

It is noted that the Council has installed containerized biomass boilers at other sites.

The containerized biomass boiler could be installed on the grass area adjacent to the New Building.

We have assumed the efficiency of the boiler to be 85%. We have modelled a carbon reduction of ca. 27.7 tonnes of CO_2e per year for this measure.

13.4.5.2 Old Building

The basement space under Spanish Ambassador's or the Old Building could potentially be used for fuel storage and boiler siting, potentially joining the building's heating systems together. However, the basement space is relatively limited and the use of this space is subject to further detailed feasibility and design.

Alternatively, the building could be served from a centralised, containerised energy centre serving both the new and old buildings to form a small district heating scheme.

We have assumed the efficiency of the boiler to be 85%. We have modelled a carbon reduction of ca. 8.7 tonnes of CO_2e per year for this measure.

13.4.6 Solar thermal

Solar thermal comprises roof mounted panels through which a working fluid is pumped to collect free heat from the sun. It is typically sized to deliver no more than the peak summer demand to avoid over-heating and as a result will typically only provide a proportion of demand in the winter. As such it is typically installed alongside a separate primary heating system such as boilers or heat pumps.

At the New Building, solar thermal could potentially contribute a proportion of the DHW demand as there is DHW demand over the peak solar months. It is estimated that an $18m^2$ solar array could be accommodated on the pitched roof to generate approximately half of the estimated annual DHW load of the calorifier in the plant room.

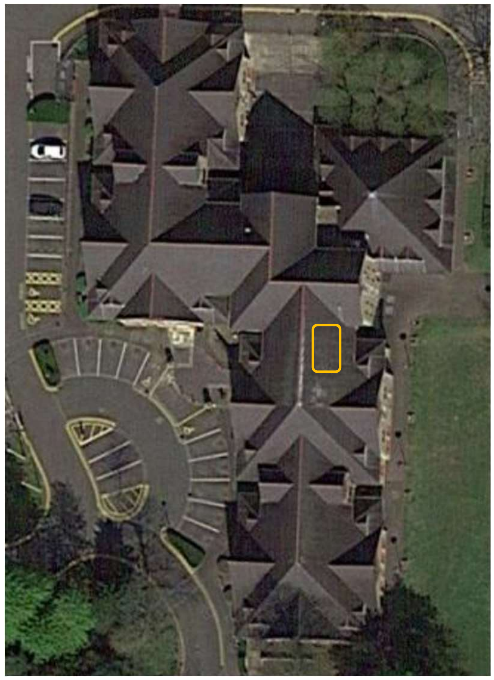


Figure 39: Solar thermal panel installation location

A new cylinder incorporating a solar thermal coil as well as electric immersions would need to be installed to replace the existing calorifier.

As solar thermal cannot provide 100% of the heat load, top up is required from the primary heat source, in this case electric immersions.

We have modelled a carbon reduction of ca. 0.6 tonnes of CO_2e per year for this measure.

13.4.7 Summary of savings for low carbon heating measures

Five main low carbon heating options have been identified, namely ASHP, GSHP, WSHP, direct electric heating and biomass boiler.

Solar thermal could be installed alongside any of the main low carbon heating options to generate DHW. As the existing heat source for DHW is already electricity and would not be changed, solar thermal savings would be same regardless of which main heating option were selected to replace the boilers.

Measure	Saving, kWh/yr	Saving, £/yr	Saving, tCO_2e/yr
Air Source Heat Pumps (AAHP or AWHP)	203,927	8,450	36.4
Air to water heat pump (Old Building)	63,591	2,734	11.4
Ground source heat pump	210,598	10,638	37.7

Measure	Saving, kWh/yr	Saving, £/yr	Saving, tCO_2e/yr
Water source heat pump	222,847	14,656	40.1
Direct electric heating (New Building)	52,566	-41,196	7.1
Direct electric heating (Old Building)	17,343	-12,435	2.4
Biomass boiler (New Building)	32,533	-13,722	27.7
Biomass boiler (Old Building)	11,222	-4,058	8.7
$18m^2$ Solar thermal	3,198	1,049	0.6

Table 23: Summary of savings for low carbon heating measures

13.5 Renewable Energy Generation

13.5.1 Solar PV

Solar photovoltaics (PV) generate electricity when exposed to sunlight. The roofs of the New Building offer some unshaded roof areas which could support the installation of solar PV.

We estimate that a 22kW system could be accommodated on the pitched roof of the New Building. The installation location is showed on Figure 40. The other buildings are listed buildings and are not recommended for installation of solar PV.

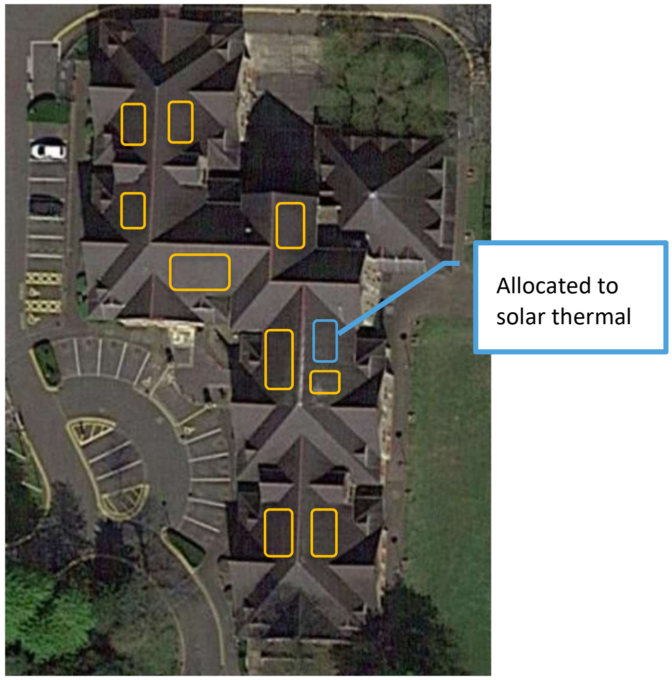


Figure 40: Solar PV panel installation location

Based on electricity consumption data for 2022/23, we estimate that the system would generate around 4% of current site electricity demand and export is expected to be relatively minimal with current demands. It is normally recommended to size a solar PV system to maximise on-site use of the solar generation as this provides the best return on investment.

Any installed system should be sized appropriately by a qualified installer.

Table 24 shows the savings for solar PV. Two options have been included for the New Building; one 22kWp system using the whole roof for solar PV and one 19kWp system retaining the ca. 18m^2 roof area identified in Figure 39 for solar thermal panels.

In comparison with Table 23, the figures in Table 24 suggest that the savings from both solar thermal and solar PV would be greater than from solar PV only. Therefore, it is recommended that both systems are installed.

13.5.2 Summary of savings for renewable generation measures

Table 24 shows the savings for renewable generation measures

Measure	Saving, kWh/yr	Saving, £/yr	Saving, tCO_2e/yr
22kWp Solar PV system	20,727	6,798	4.0
19kWp Solar PV system	17,901	5,872	3.5

Table 24: Summary of savings for renewable generation measures

14 Decarbonisation Pathways

All of the measures discussed in Sections 13.2 to 13.5 above form a decarbonisation pathway.

In order to provide a fair comparison of each of the measures, the carbon impact shown is based on the 2022 emissions factors for the UK, regardless of planned implementation timescale of each measure.

Five options are shown for five different heat decarbonisation options in the New Building – ASHP, GSHP, WSHP, direct electric heating or biomass boiler and three options are shown for the Old Building – ASHP, direct electric heating or biomass boiler. This results in eight different waterfall diagrams. The diagrams show the cumulative effect of the measure in all heating scenarios. The x-axis shows each of the steps and the y-axis shows the carbon emissions at each stage.

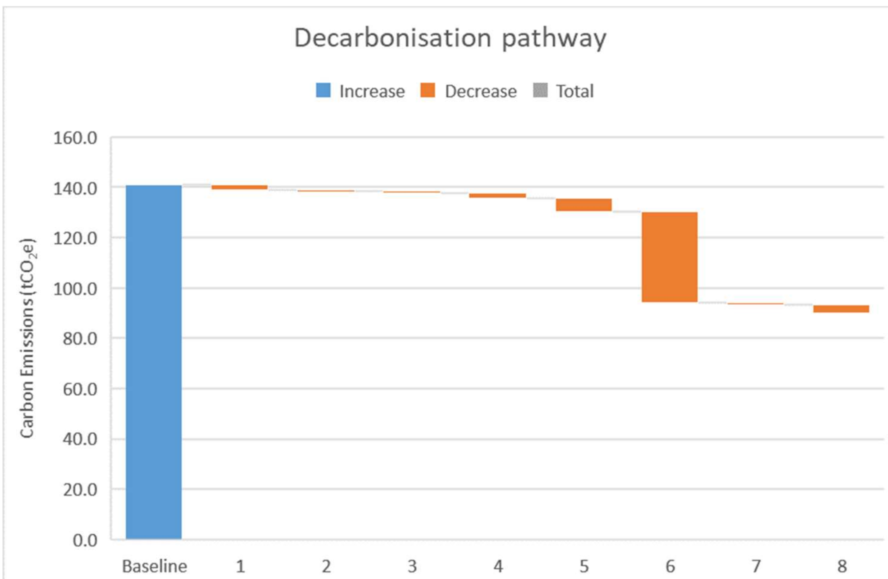


Figure 41: Water fall diagram of cumulative reductions – New Building ASHP scenario

	Stage	Benefit (tCO_2e)	Total emissions (tCO_2e)
Baseline	Baseline	-	140.8
Heating controls	1	-1.8	139.0
Replace Chamber AHU belt driven fan with direct drive fan	2	-0.4	138.6
Plant room pipe and valve insulation	3	-0.9	137.7
Roof insulation	4	-2.3	135.4
Glazing	5	-5.0	130.4
ASHP	6	-36.4	94.0
Solar thermal	7	-0.6	93.4
Solar PV	8	-3.5	89.9

Table 25: Cumulative carbon reductions – New Building ASHP scenario

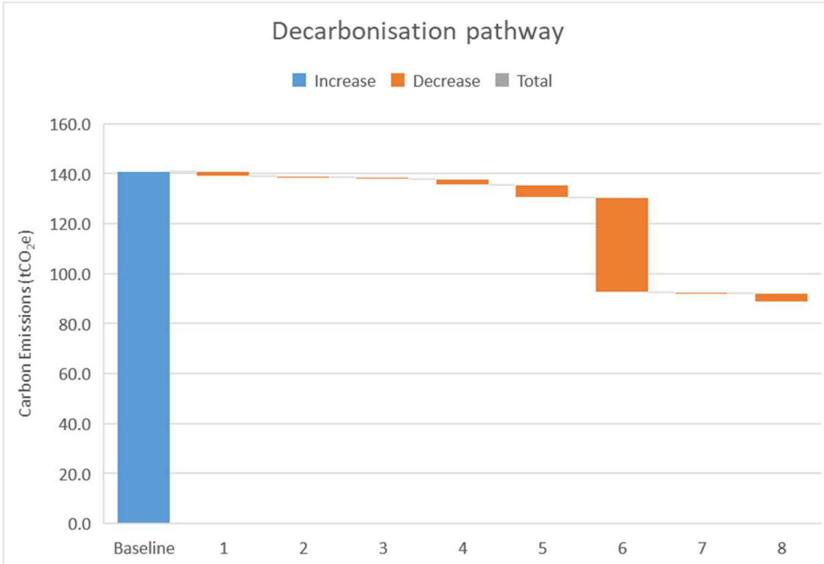


Figure 42: Water fall diagram of cumulative reductions – New Building GSHP scenario

	Stage	Benefit (tCO_2e)	Total emissions (tCO_2e)
Baseline	Baseline	-	140.8
Heating controls	1	-1.8	139.0
Replace Chamber AHU belt driven fan with direct drive fan	2	-0.4	138.6
Plant room pipe and valve insulation	3	-0.9	137.7
Roof insulation	4	-2.3	135.4
Glazing	5	-5.0	130.4
GSHP	6	-37.7	92.7
Solar thermal	7	-0.6	92.1
Solar PV	8	-3.5	88.7

Table 26: Cumulative carbon reductions – New Building GSHP scenario

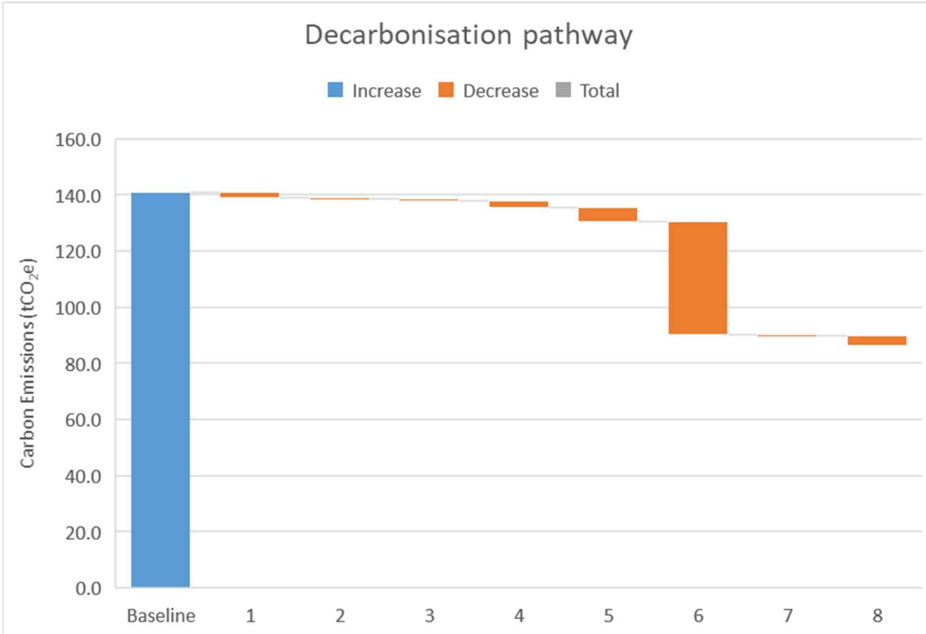


Figure 43: Water fall diagram of cumulative reductions – New Building WSHP scenario

	Stage	Benefit (tCO_2e)	Total emissions (tCO_2e)
Baseline	Baseline	-	140.8
Heating controls	1	-1.8	139.0
Replace Chamber AHU belt driven fan with direct drive fan	2	-0.4	138.6
Plant room pipe and valve insulation	3	-0.9	137.7
Roof insulation	4	-2.3	135.4
Glazing	5	-5.0	130.4
WSHP	6	-40.1	90.4
Solar thermal	7	-0.6	89.7
Solar PV	8	-3.5	86.3

Table 27: Cumulative carbon reductions – New Building WSHP scenario

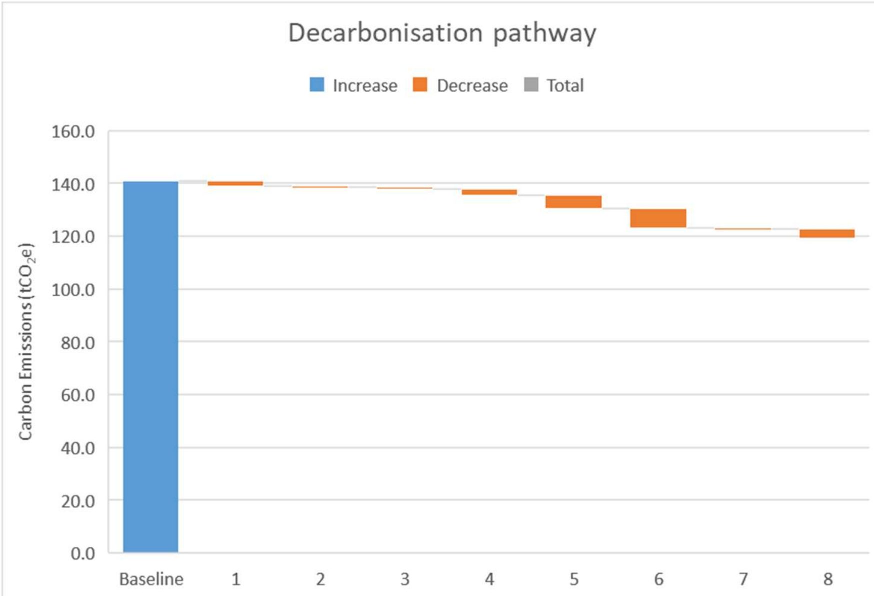


Figure 44: Water fall diagram of cumulative reductions – New Building direct electric heating scenario

	Stage	Benefit (tCO_2e)	Total emissions (tCO_2e)
Baseline	Baseline	-	140.8
Heating controls	1	-1.8	139.0
Replace Chamber AHU belt driven fan with direct drive fan	2	-0.4	138.6
Plant room pipe and valve insulation	3	-0.9	137.7
Roof insulation	4	-2.3	135.4
Glazing	5	-5.0	130.4
Direct Electric Heating	6	-7.1	123.3
Solar thermal	7	-0.6	122.7
Solar PV	8	-3.5	119.2

Table 28: Cumulative carbon reductions – New Building direct electric heating scenario

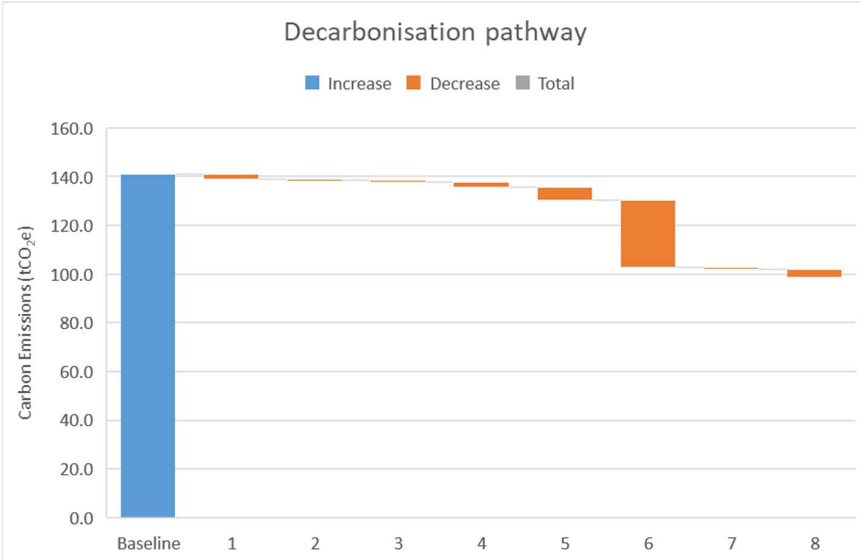


Figure 45: Water fall diagram of cumulative reductions – New Building biomass boiler scenario

	Stage	Benefit (tCO_2e)	Total emissions (tCO_2e)
Baseline	Baseline	-	140.8
Heating controls	1	-1.8	139.0
Replace Chamber AHU belt driven fan with direct drive fan	2	-0.4	138.6
Plant room pipe and valve insulation	3	-0.9	137.7
Roof insulation	4	-2.3	135.4
Glazing	5	-5.0	130.4
Biomass boiler	6	-27.7	102.7
Solar thermal	7	-0.6	102.1
Solar PV	8	-3.5	98.7

Table 29: Cumulative carbon reductions – New Building biomass boiler scenario

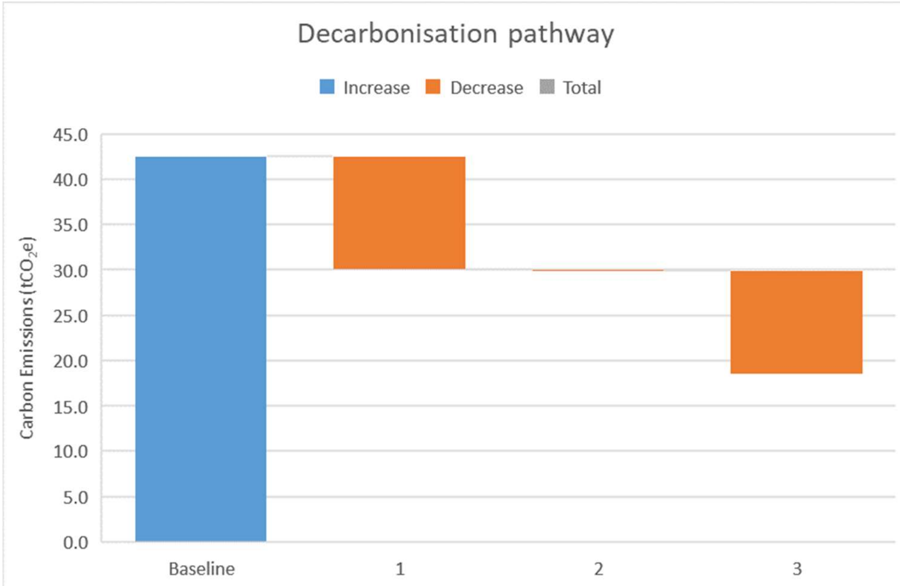


Figure 46: Water fall diagram of cumulative reductions – Old Building ASHP scenario

	Stage	Benefit (tCO_2e)	Total emissions (tCO_2e)
Baseline	Baseline	-	42.6
Heating controls	1	-12.5	30.1
Roof insulation	2	-0.2	29.9
ASHP	3	-11.4	18.5

Table 30: Cumulative carbon reductions – Old Building ASHP scenario

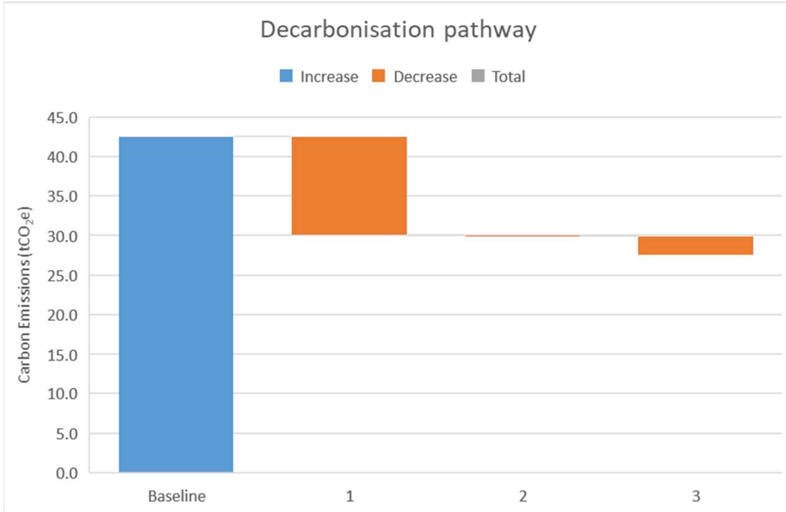


Figure 47: Water fall diagram of cumulative reductions – Old Building direct electric heating scenario

	Stage	**Benefit (tCO_2e)**	**Total emissions (tCO_2e)**
Baseline	Baseline	-	42.6
Heating controls	1	-12.5	30.1
Roof insulation	2	-0.2	29.9
Direct Electric Heating	3	-2.4	27.5

Table 31: Cumulative carbon reductions – Old Building direct electric heating scenario

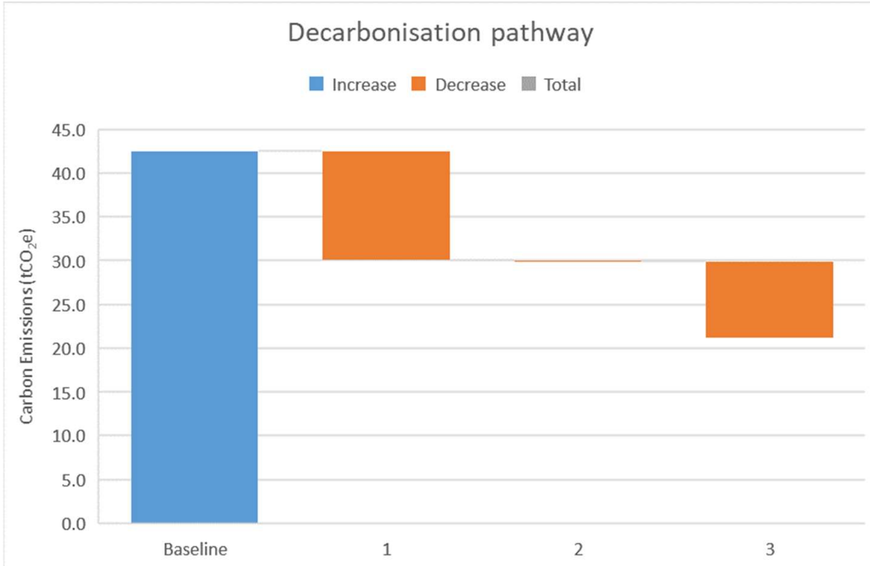


Figure 48: Water fall diagram of cumulative reductions – Old Building biomass boiler scenario

	Stage	Benefit (tCO_2e)	Total emissions (tCO_2e)
Baseline	Baseline	-	42.6
Heating controls	1	-12.5	30.1
Roof insulation	2	-0.2	29.9
Biomass boiler	3	-8.7	21.2

Table 32: Cumulative carbon reductions – Old Building biomass boiler scenario

14.1.1 Impact of grid decarbonisation

Both the UK gas and electricity grid supplies are decarbonising as a result of changes in the energy supply mix, including injection of biogas into the gas grid and a large increase in wind generation capacity.

Emissions factors are only published annually (in arrears) by UK and we are not aware of any published future predictions.

The table below shows the historic emission factors (to three decimal places) taken from DESNZ (formally BEIS) Government Conversion Factors for Company Reporting of Greenhouse Gas Emissions.

Year	Emissions Factor ($kgCO_2e/kWh$)								Average Annual Variance
	2016	2017	2018	2019	2020	2021	2022	2023	
Electricity (Scope2)	0.412	0.351	0.283	0.256	0.233	0.212	0.193	0.207	-9.1%
Gas (Scope1)	0.183	0.184	0.183	0.183	0.183	0.183	0.183	0.183	-0.005%

Table 33: Historic Emissions Factors

We have predicted emission factors for 2024 onwards, based on the average annual percentage variance over the last eight years.

It should be noted that the historic emission factor trends may not be representative of future changes in emission factors.

Year	Emissions Factor ($kgCO_2e/kWh$)					
	2022	2023	2024	2025	2026	2027
Electricity (Scope2)	0.193	0.207	0.188	0.171	0.156	0.142
Gas (Scope1)	0.183	0.183	0.183	0.183	0.183	0.183

Table 34: Predicted Emissions Factors

The impact of changing emissions factors for the New Building and the Old Building is shown in the table below. This assumes that all measures were implemented by the end of 2022 and that the ASHP with solar thermal option is adopted for the New Building and the ASHP option is adopted for the Old Building.

This data is presented solely to allow the impact of future grid decarbonisation to be assessed.

Year	Site Emissions (tCO_2e) Assuming all measures have been completed					
	2022	**2023**	**2024**	**2025**	**2026**	**2027**
Gas (Scope 1)	0	0	0	0	0	0
Electricity (Scope 2)	108.5	116.1	105.6	96.1	87.4	79.4
Total	**108.5**	**116.1**	**105.6**	**96.1**	**87.4**	**79.4**

Table 35: Impact of changing carbon factors

The impact of the decarbonisation of the national grid means that the footprint could reduce by a further 29.0 tCO_2e over five years without any further action required by the site.

15 Financial Analysis

15.1 Project costs

Concept have made estimates of the likely project costs using published pricing books[3] and historic cost estimates that we hold for similar projects. We have not engaged a quantity surveyor and it should be noted that these estimated costs are solely for the purposes of comparing the individual measures.

Only projects with tangible or quantified energy benefits have been costed.

15.1.1 Replace Chamber AHU belt driven fan with direct drive fan

We have estimated the cost of replacing fans based on SPONs price book rates for supply and installation of extract fan, which are provided on a cost per fan basis.

We have added additional costs for design and making good at 30% of the base cost.

Item	Qty	Cost ea.	Sub-total
Supply and installation of fans	1	£4,200	£4,200
Design and making good	30%	-	£1,260
TOTAL			**£5,500**

Table 36: Replace belt driven fans with direct driven fans cost estimate

15.1.2 Plant room pipe and valve insulation

Installation of pipe and valve insulation does not typically require specialist contractors and can normally be completed by site maintenance personnel. We have allowed for approximate linear meterage and valve numbers observed on site, with a small allowance for installation time cost.

Item	Qty	Cost ea.	Sub-total
Installation of pipe insulation, per m	10	£30	£300
Installation of valve insulation, per m	30	£50	£1,500
Installation	40	£20	£800
TOTAL			**£2,600**

Table 37: Pipe and valve insulation cost estimate

[3] SPON's Mechanical and Electrical Services Price Book

15.1.3 Roof insulation

We have estimated the cost based on the Spon's rate for mineral fibre quilt insulation.

We have included additional costs for feasibility, design and making good at 30% of the base cost. Table 38 shows the cost of roof insulation for the New Building and Table 39 shows the cost for the Old Building.

Item	Qty	Cost ea.	Sub-total
Supply and install of roof insulation per m2	1,900	£30	£57,000
Feasibility, design and making good	30%	-	£17,100
TOTAL			**£74,100**

Table 38: Roof insulation (New Building) throughout cost estimate

Item	Qty	Cost ea.	Sub-total
Supply and install of roof insulation per m2	1,037	£10	£10,370
Feasibility, design and making good	30%	-	£3,130
TOTAL			**£13,500**

Table 39: Roof insulation (Old Building) throughout cost estimate

15.1.4 Glazing

We have estimated the cost based on the Spon's rate for factory-made double hermetically sealed units.

We have added additional costs for replacement of glazing at 30% of the base cost and reinstate surface mounted equipment at 30% of the base cost.

Item	Qty	Cost ea.	Sub-total
Supply of double glazed unit per m^2	304	£190	£57,760
Replacement of glazing per m^2	304	£100	£30,400
Feasibility, design and making good	30%	-	£26,440
TOTAL			**£114,600**

Table 40: Roof insulation throughout cost estimate

15.1.5 Air source heat pumps

Pricing for ASHPs is subject to detailed design to determine the capacity of plant items, which is beyond the scope of this study. However, we have estimated a total required heating capacity of ca. 573kW (including 12kW AHU reheat coils) for the New Building and ca. 310kW for the Old Building (section 12.3). The cost to supply and install AWHP or AAHP has been estimated based on past manufacturer estimates.

Table 41 and Table 42 shows the cost estimate of AWHP for the New Building and the Old Building. We have added a provisional sum for complete replacement of internal distribution pipework, control integrations and upgrades to the grid electricity supply. We have also included additional costs for design and making good at 30% of the base cost.

Item	Qty	Cost ea.	Sub-total
Supply and installation of ASHP per kW	561	£1,300	£729,300
Replacement of existing emitters, LTHW distribution and AHU heating coils	Provisional sum	£100,000	£100,000
ASHP Plant compound	1	£5,000	£5,000
New pumps	4	£2,500	£10,000
Control integrations	Provisional sum	£10,000	£10,000
Grid electricity supply upgrades	Provisional sum	£50,000	£50,000
Design and making good	30%	-	£271,300
TOTAL			**£1,175,600**

Table 41: AWHP (New Building) cost estimate

Item	Qty	Cost ea.	Sub-total
Supply and installation of ASHP per kW	310	£1,300	£403,000
Replacement of existing emitters and LTHW distribution	Provisional sum	£80,000	£80,000
ASHP Plant compound	1	£5,000	£5,000
New pumps	4	£2,500	£10,000
Control integrations	Provisional sum	£10,000	£10,000
Grid electricity supply upgrades	Provisional sum	£50,000	£50,000
Design and making good	30%	-	£167,400
TOTAL			**£725,400**

Table 42: AWHP (Old Building) cost estimate

Table 43 shows the cost estimate for AAHP in the new building only. We have estimated the cost of FCUs based on Spon's price book. We have added provisional sums for controls integration, upgrades to the grid electricity supply. We have also included an additional cost for design and making good at 30% of the base cost.

Item	Qty	Cost ea.	Sub-total
Supply and installation of ASHP per kW	561	£1,300	£729,300
Supply and installation of FCU per kW	561	£300	£168,300
ASHP Plant compound	1	£5,000	£5,000
Control integrations	Provisional sum	£10,000	£10,000
Grid electricity supply upgrades	Provisional sum	£100,000	£100,000
Design and making good	30%	-	£303,800
TOTAL			**£1,316,400**

Table 43: AAHP cost estimate

15.1.6 Ground Source Heat Pump

Pricing for GSHPs is subject to detailed design to determine the capacity of plant items, which is beyond the scope of this study. However, as with the ASHP options an estimated capacity of ca. 561kW was assumed. A ca. 160kW GSHP could be installed based on the grass area, with top up from a ca. 400kW AWHP. The cost to supply and install the GSHP and AWHP were based on past manufacturer estimates.

We have added a provisional sum for complete replacement of internal distribution pipework, control integrations and upgrades to the grid electricity supply. We have also included additional costs for design and making good at 30% of the base cost.

Item	Qty	Cost ea.	Sub-total
Supply and installation of GSHP per kW	160	£2,500	£400,000
Supply and installation of ASHP per kW	401	£1,300	£521,300
Replacement of existing emitters, LTHW distribution and AHU heating coils	Provisional sum	£100,000	£100,000
External pipework from plant room to the grass area per m	30	£200	£6,000
New pumps	4	£2,500	£10,000
Control integration	Provisional sum	£10,000	£10,000
Grid electricity supply upgrades	Provisional sum	£100,000	£100,000
Design and making good	30%	-	£344,200
TOTAL			**£1,491,500**

Table 44: GSHP cost estimate

15.1.7 Water Source Heat Pumps

We have added a provisional sum for applying abstraction license based on the Environment Agency's charging scheme[4] with an annual renewal fee of ca. £1,200.

We have added a provisional sum for control integration and grid electricity supply upgrades, and additional costs for design and making good at 30% of the base cost.

Item	Qty	Cost ea.	Sub-total
Supply and installation of WSHP per kW	561	£1,300	£729,300
New PHE for river water	1	£10,000	£10,000
External pipework from plant room to the New River per m	40	£200	£8,000
Replacement of existing emitters, LTHW distribution and AHU heating coils	Provisional sum	£100,000	£100,000
New pump	4	£2,500	£10,000
Control integration	Provisional sum	£10,000	£10,000
Grid electricity supply upgrades	Provisional sum	£100,000	£100,000
Abstraction license	Provisional sum	£2,000	£2,000
Design and making good	30%	-	£290,200
TOTAL			**£1,259,500**

Table 45: WSHP for pool water cost estimate

15.1.8 Direct electric heating

We have estimated the cost of wall mounted electric heaters to replace radiators based on typical market rates, with additional costs for removal of existing radiators and design costs have been included at ca. 30% of the base cost each.

We have also added a provisional sum for control integration and grid electricity supply upgrades, and additional costs for design and making good at 30% of the base cost.

[4] The Environment Agency (Environmental Permitting and Abstraction Licensing) (England) Charging Scheme 2022

Item	Qty	Cost ea.	Sub-total
Supply of wall mounted electric heater	171	£350	£59,850
Installation of wall mounted electric heater	171	£30	£5,130
Removal of existing radiators and pipework, % of supply and installation cost	30%	-	£17,955
Controls integration	Provisional sum	£10,000	£10,000
Grid electricity supply upgrades	Provisional sum	£100,000	£100,000
Design and making good	30%	-	£57,865
TOTAL			**£250,800**

Table 46: Direct electric heating (New Building) cost estimate

Item	Qty	Cost ea.	Sub-total
Supply of wall mounted electric heater	104	£350	£36,400
Installation of wall mounted electric heater	104	£30	£3,120
Removal of existing radiators and pipework, % of supply and installation cost	30%	-	£10,920
Controls integration	Provisional sum	£10,000	£10,000
Grid electricity supply upgrades	Provisional sum	£100,000	£100,000
Design and making good	30%	-	£48,160
TOTAL			**£208,600**

Table 47: Direct electric heating (Old Building) cost estimate

15.1.9 Biomass boiler

We have estimated the cost of biomass boiler based on the Spon's capital cost for biomass boiler, with additional costs for external pipework for the New Building and fuel storage room refurbishment for the Old Building, and top up electric boilers.

We have also added a provisional sum for control integration, and additional costs for design and making good at 30% of the base cost.

Item	Qty	Cost ea.	Sub-total
Supply and installation of biomass boiler per kW	281	£500	£140,500
Supply and installation of 40ft container	1	£15,000	£15,000
Supply and installation of top up electric boiler - 140kW	2	£5,000	£10,000
External pipework from plant room to the containerised biomass boiler per m	10	£150	£1,500
New pumps	4	£2,500	£10,000
Control integration	Provisional sum	£10,000	£10,000
Design and making good	30%	-	£56,100
TOTAL			**£243,100**

Table 48: Biomass boiler (New Building) cost estimate

Item	Qty	Cost ea.	Sub-total
Supply and installation of biomass boiler per kW	155	£500	£77,500
Supply and installation of top up electric boiler - 75kW	2	£4,000	£8,000
Fuel storage room refurbishment	Provisional sum	£20,000	£20,000
New pump	4	£2,500	£10,000
Control integration	Provisional sum	£10,000	£10,000
Design and making good	30%	-	£37,700
TOTAL			**£163,200**

Table 49: Biomass boiler (Old Building) cost estimate

15.1.10 Solar thermal

We have estimated the cost of installing 18m^2 solar thermal system based on approximate Spons whole system costs per m^2 of collector area and additional allowances for a twin coil cylinder.

An allowance has been included for access to ensure panels, frames and ballast can be safely lifted to the roof.

We have added additional costs for design and making good at 30% of the base cost.

Item	Qty	Cost ea.	Sub-total
Supply and installation of roof mounted solar thermal system per m^2 of aperture area	18	£750	£13,500
Solar thermal coil	1	£500	£500
Allowance for access	1	£10,000	£10,000
Design and making good	30%	-	£7,200
TOTAL			**£31,200**

Table 50: Solar thermal cost estimate

15.1.11 Solar PV

Costs for solar PV installation have been based on published government solar PV costs per kW for Q1 2023 for systems 10 - 50kW. Two options have been costed; a 22kWp system assuming all suitable roof space is used for solar PV and a 20kWp system assuming $18m^2$ is allocated to solar thermal panels.

An allowance has been included for access equipment to ensure panels, frames and ballast can be safely lifted to the roof.

We have added additional costs for design and making good at ca. 30% of the base cost.

Item	Qty	Cost ea.	Sub-total
Supply and installation of roof mounted solar PV	22	£1,350	£29,700
Allowance for access	Provisional sum	£50,000	£50,000
Design and making good	30%	-	£23,900
TOTAL			**£103,600**

Table 51: 22kWp Solar PV cost estimate

Item	Qty	Cost ea.	Sub-total
Supply and installation of roof mounted solar PV	19	£1,350	£25,650
Allowance for access	Provisional sum	£50,000	£50,000
Design and making good	30%	-	£22,650
TOTAL			**£98,300**

Table 52: 20kWp Solar PV cost estimate

15.2 Summary of NPV results

Table 53 shows the summary of Net Present Value (NPV) of the saving measures. It concludes that replacing the Chamber AHU fans, plant room pipe and valve insulation, glazing, solar thermal and solar PV give a positive NPV, while other measures give a negative NPV. The low carbon heating measures would give a significantly higher carbon saving although they give a negative NPV.

Measure	Persistence Factor	Guideline Cost, £	NPV, £	Annual Carbon Saving, tCO_2e
Energy Efficiency				
Replace Chamber AHU belt driven fan with direct drive fan	24	5,500	13,222	0.4
Plant room pipe and valve insulation	23	2,600	13,687	0.9
Roof insulation (New Building)	30	74,100	-17,196	2.3
Roof insulation (Old Building)	30	13,500	-8,855	0.2
Glazing	28	114,600	22,246	5.0
Low Carbon Heating				
AWHP (New Building)	20	1,175,600	-978,358	36.4
AWHP (Old Building)	20	725,400	-661,573	11.4
AAHP	20	1,316,400	-1,119,158	36.4
GSHP	25	1,491,500	-1,169,113	37.7
WSHP	25	1,259,500	-815,357	40.1
Direct electric heating (New Building)	10	250,800	-697,069	7.1
Direct electric heating (Old Building)	10	208,600	-343,305	2.4
Biomass boiler (New Building)	20	243,100	-548,135	27.7
Biomass boiler (Old Building)	20	163,200	-253,409	8.7
Solar thermal	25	31,200	591	0.6

Measure	Persistence Factor	Guideline Cost, £	NPV, £	Annual Carbon Saving, tCO_2e
Renewable Energy Generation				
Solar PV 22kWp	23	103,600	83,084	4.0
Solar PV 19kWp (if solar thermal also implemented)	23	98,300	62,927	3.5

Table 53: Summary of NPV of saving measures

15.3 Sensitivity Analysis

The results indicated in the previous section are dependent on the modelled values, which may be different following detailed feasibility. To provide some indication of how key metrics will affect the investment, the following tables present the results of a basic sensitivity analysis.

This analysis has been carried out by changing input values of Capex and the gas tariff. For analysis of changing Capex, the replacement option Capex is varied by a percentage. Similarly, adjusting the gas tariff changes the relative fuel cost between the current system and the alternative.

Table 54 shows changing values of Net Present Value (NPV) when the replacement option Capex is adjusted up or down by 10% or 20%. All options remain negative with a 20% reduction in Capex.

Table 55 shows changing values of Net Present Value (NPV) when the gas tariff is adjusted up or down by 10% or 20%. All options benefit from a more expensive gas tariff due to the increased savings over the base case and most of them remain negative with a 20% increase in gas tariff, while WSHP has a positive NPV with increase in gas tariff.

Option	Capex Adjustment			
	-20%	-10%	10%	20%
AWHP (New Building)	-743,238	-860,798	-1,095,918	-1,213,478
AWHP (Old Building)	-516,493	-589,033	-734,113	-806,653
AAHP	-855,878	-987,518	-1,250,798	-1,382,438
GSHP	-870,813	-1,019,963	-1,318,263	-1,467,413
WSHP	-563,457	-689,407	-941,307	-1,067,257
Direct electric heating (New Building)	-646,909	-671,989	-722,149	-747,229
Direct electric heating (Old Building)	-301,585	-322,445	-364,165	-385,025
Biomass boiler (New Building)	-499,515	-523,825	-572,445	-596,755
Biomass boiler (Old Building)	-220,769	-237,089	-269,729	-286,049

Table 54: Sensitivity analysis of NPV results with changing Capex

Option	Gas Tariff Adjustment			
	-20%	-10%	10%	20%
AWHP (New Building)	-1,762,293	-1,370,325	-586,391	-194,424
AWHP (Old Building)	-821,050	-741,312	-581,835	-502,097
AAHP	-1,903,093	-1,511,125	-727,191	-335,224
GSHP	-2,186,892	-1,678,003	-660,223	-151,334
WSHP	-1,833,136	-1,324,246	-306,467	202,423
Direct electric heating (New Building)	-1,060,885	-878,977	-515,161	-333,253
Direct electric heating (Old Building)	-417,316	-380,311	-306,299	-269,293
Biomass boiler (New Building)	-696,071	-622,103	-474,167	-400,199
Biomass boiler (Old Building)	-299,289	-276,349	-230,470	-207,530

Table 55: Sensitivity analysis of NPV results with changing gas tariff

16 Marginal Abatement Cost Curves (MACC)

A Marginal Abatement Cost Curve uses the NPV of each project and the total carbon that the project saves in its lifetime to provide a comparative cost of abating each tonne of Carbon Dioxide Equivalent.

The carbon factors have been fixed at the 2022 values and exclude the impact of grid decarbonisation.

Costs of £0.328kWh for electricity and £0.119/kWh for gas have been assumed, as has a fuel price inflation of 5% per annum.

A discount rate of 3.5% has been used.

This assumes that the ASHP with solar thermal option is adopted for the New Building and the AWHP option is adopted for the Old Building. Figure 49 and Figure 50 show the MACC for the New Building and the Old Building respectively.

It should be noted that in the current market, contractual rates for all fuel supplies are typically significantly higher than those stated above. This will improve the cost effectiveness of measures in the short term as lifetime financial savings and NPV will increase.

The Y axis of the MACC is shown in £ per tonne of carbon abated based on the NPV. Note that a positive number indicates a cost whilst a negative number indicates a saving.

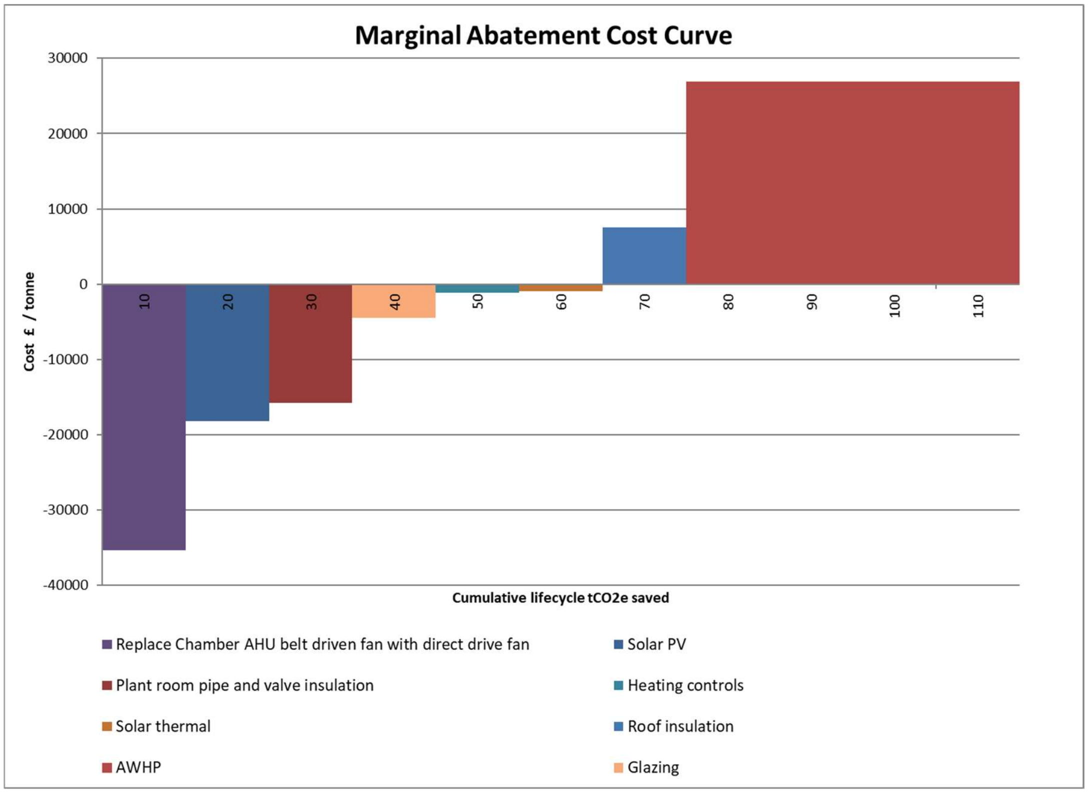


Figure 49: Marginal Abatement Cost Curve for New Building

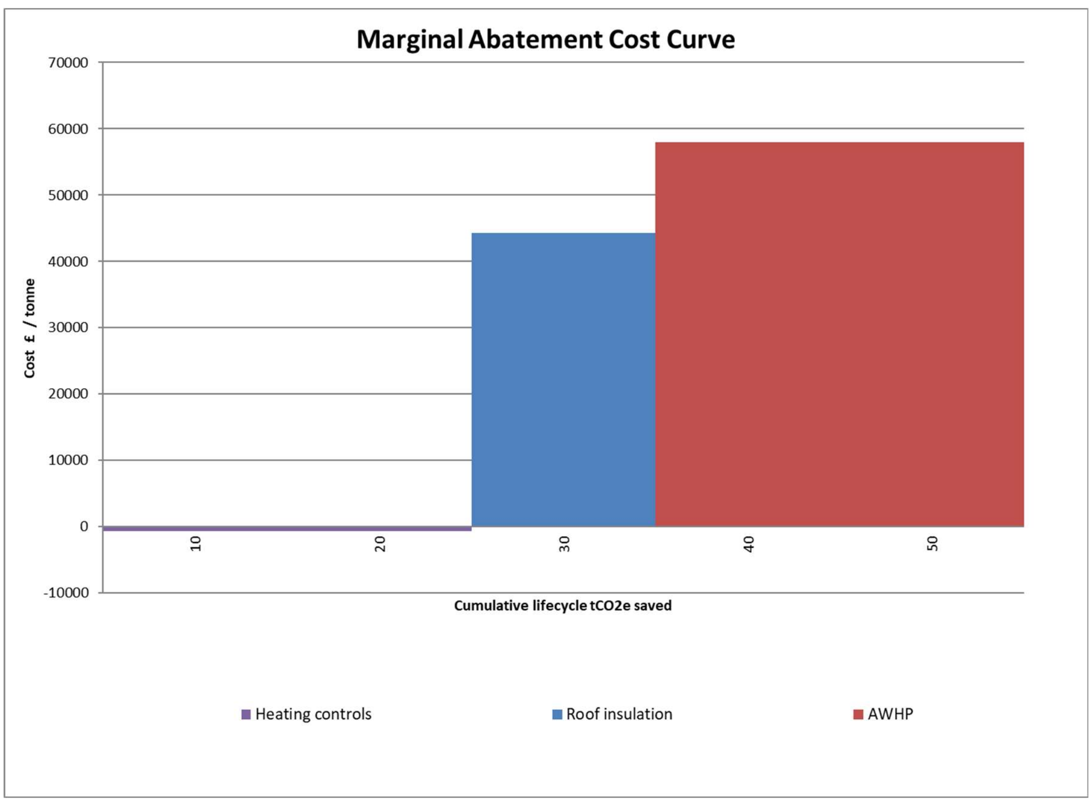


Figure 50: Marginal Abatement Cost Curve for Old Building

17 Summary and Conclusions

Bishops College comprises of several office buildings, includes the New Building and some old buildings. The typical occupancy hours of the buildings are 09:00hrs to 17:00hrs Monday to Friday, with no occupancy at weekends.

Concept has visited site to identify current performance and potential improvements. A number of potential savings measures have been identified including one zero costed measure and some costed measures.

A bulk energy simulation model of the site has been created using RETScreen. The purpose of the baseline model is to attempt to replicate the building in its current condition and model the impact of the identified measures.

Savings were modelled iteratively in order of the energy hierarchy as follows:

- Energy saving (through behaviours and controls)
- Energy efficiency (through improvements to the building and equipment)
- Low carbon heat sources
- Renewable generation

The zero costed energy saving measure is adjusting the heating control. The boilers in the New Building and the Old Building are operating longer than occupancy hours which could be reduced to match it.

A number of energy efficiency measures were identified. These measures include:

- Replace Chamber AHU belt driven fan with direct drive fan;
- Plant room pipe and valve insulation;
- Roof insulation, and
- Glazing

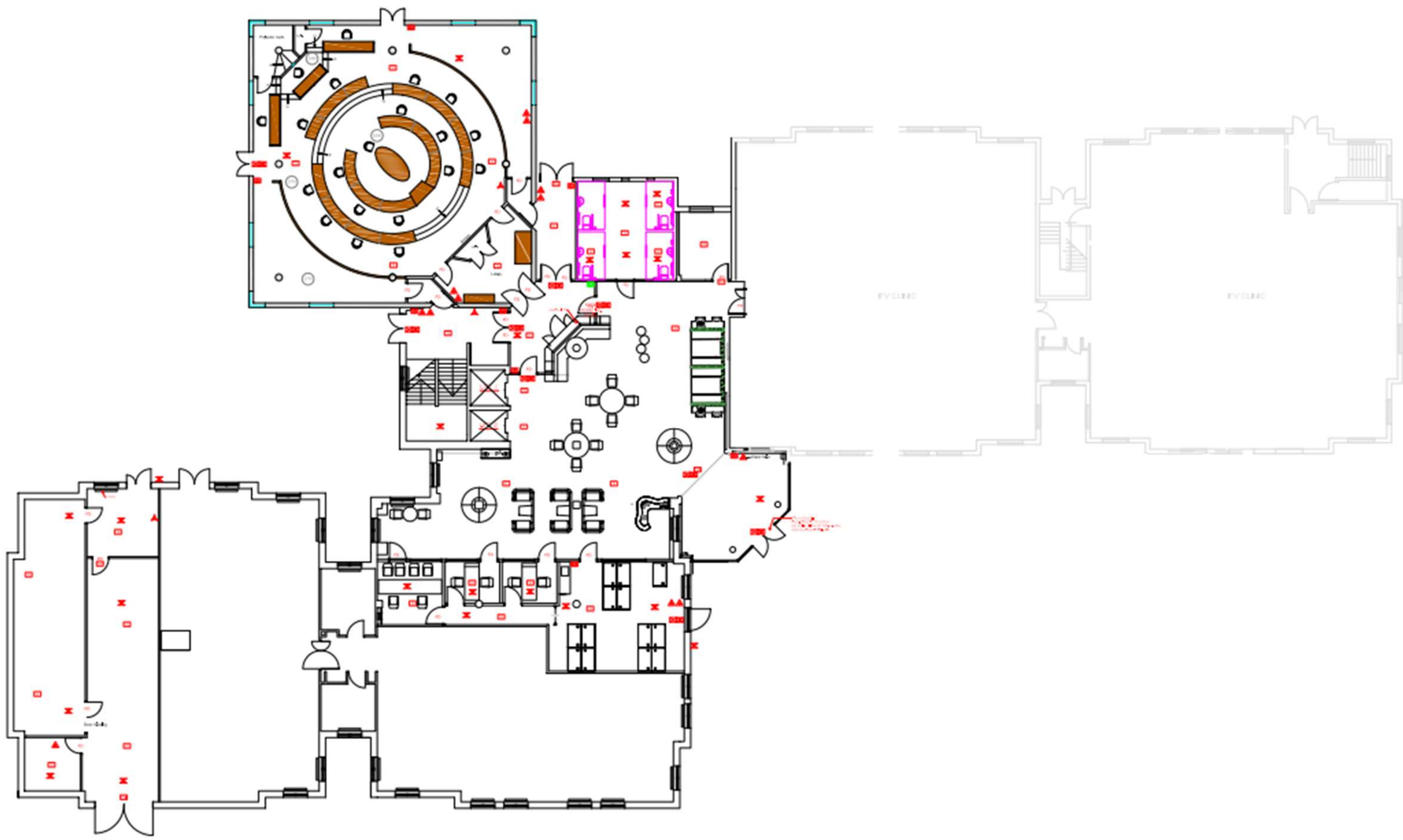
Low carbon heating options include either installing an ASHP, GSHP, WSHP, direct electric heating or biomass boilers to replace the existing gas boilers to provide space heating. A solar thermal system could be implemented to provide a proportion of DHW to the site. The ASHP option could consist of Air to Water Heat Pumps and Air to Air Heat Pumps; heat pump systems in general would provide a greater emissions reduction but at significantly higher cost than direct electric heating.

Solar thermal system would give some benefit and would be installed on the pitched roof of the New Building. Solar PV could also be installed on the roof to provide further emissions reduction.

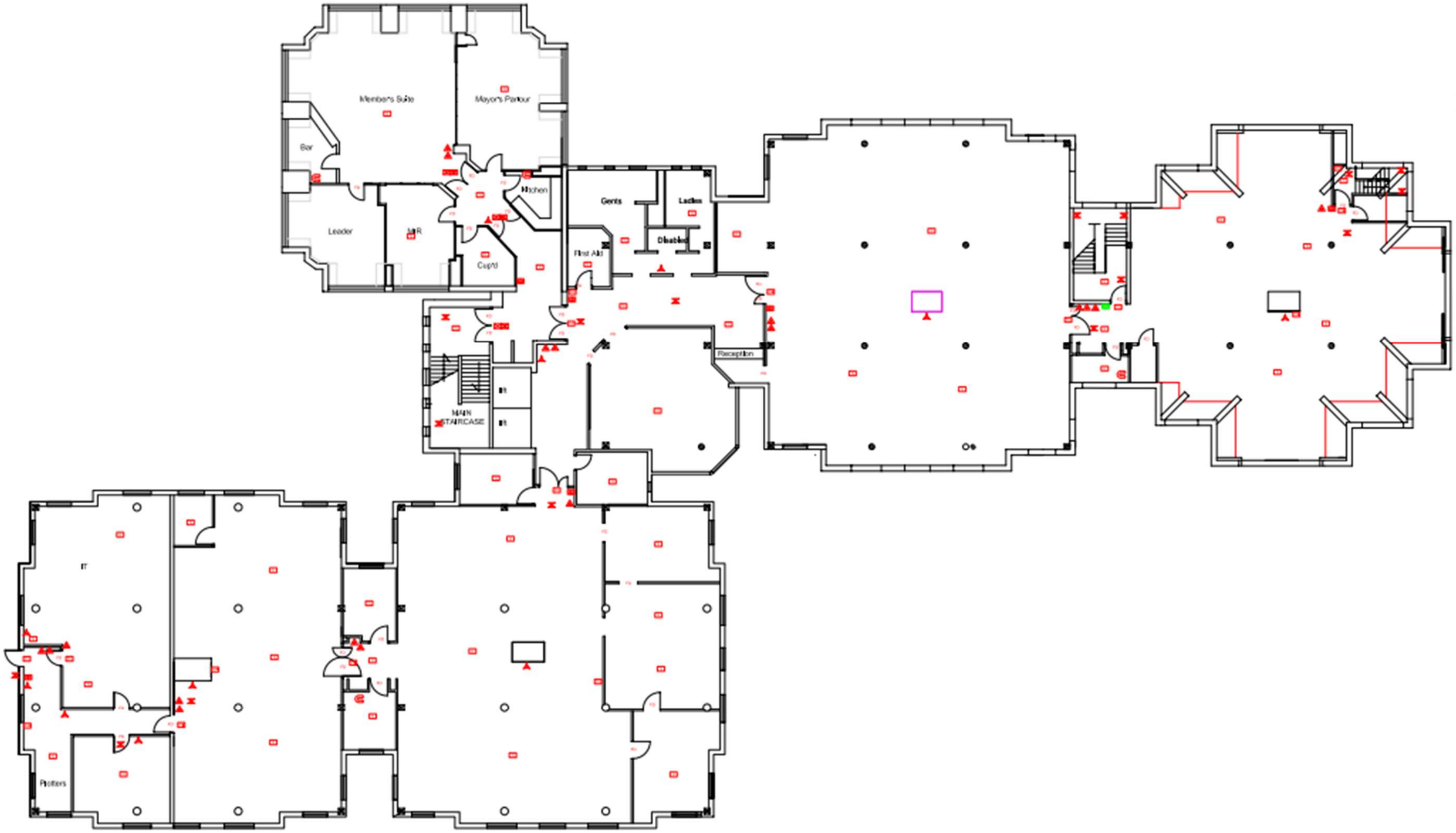
The financial analysis suggests that replace Chamber AHU belt driven fan with direct drive fan, plant room pipe and valve insulation, glazing, solar thermal and solar PV measures would give a positive NPV, while all other measures give a negative NPV.

If all of the recommended options were taken up and ASHP was adopted for the New Building and the Old Building as the low carbon heat sources, the New Building and the Old Building would still have a residual carbon footprint of around 108.5 tCO_2e even after a considerable investment. However, this would be entirely from purchased electricity; grid electricity supplies are expected to decarbonise further over time without intervention as more renewables are introduced to the supplies. Based on historical trends, we have estimated that this could reduce emissions by a further 29.0 tCO_2e within a 5-year period.

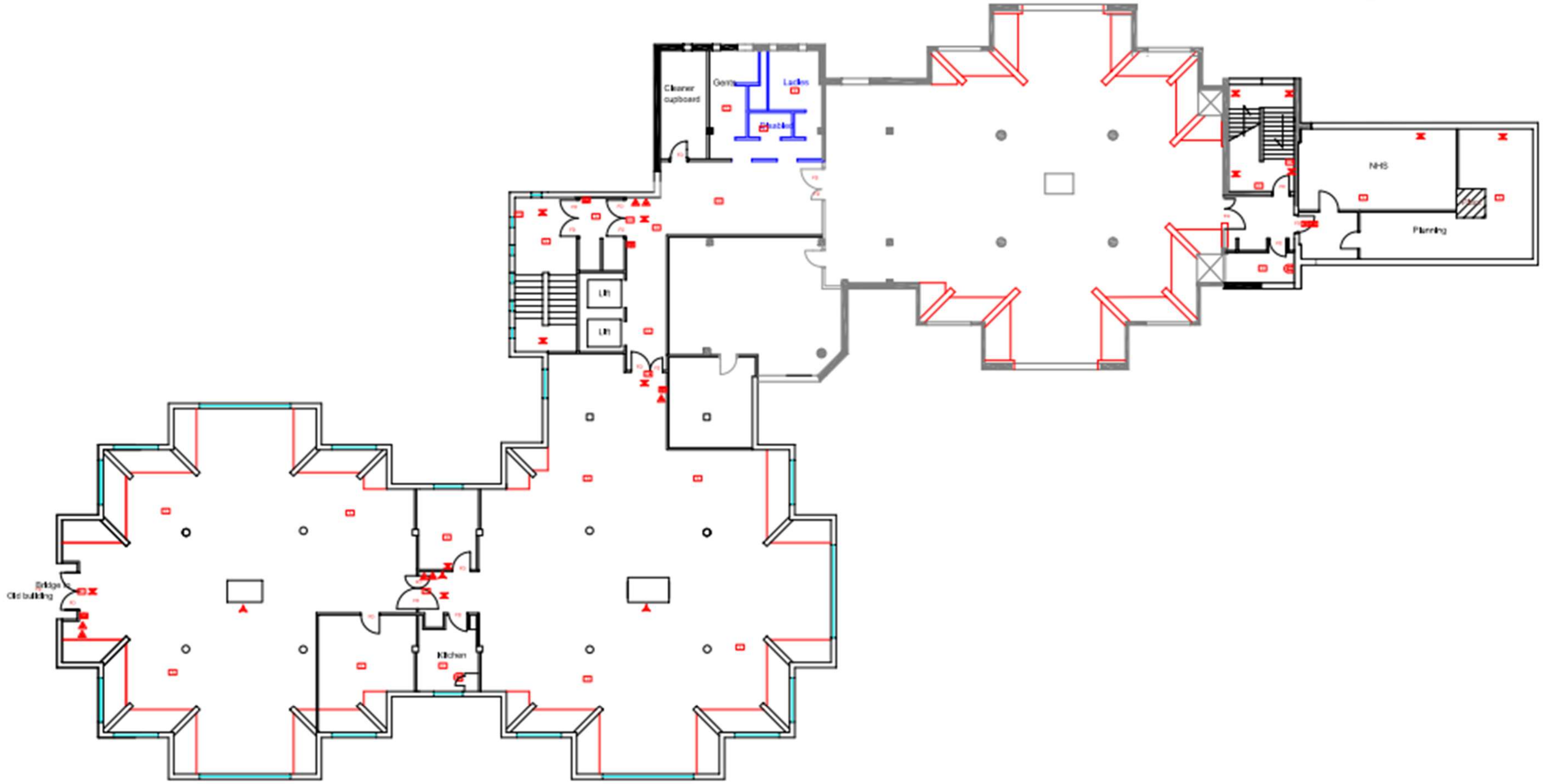
Appendix A – Floor Plan



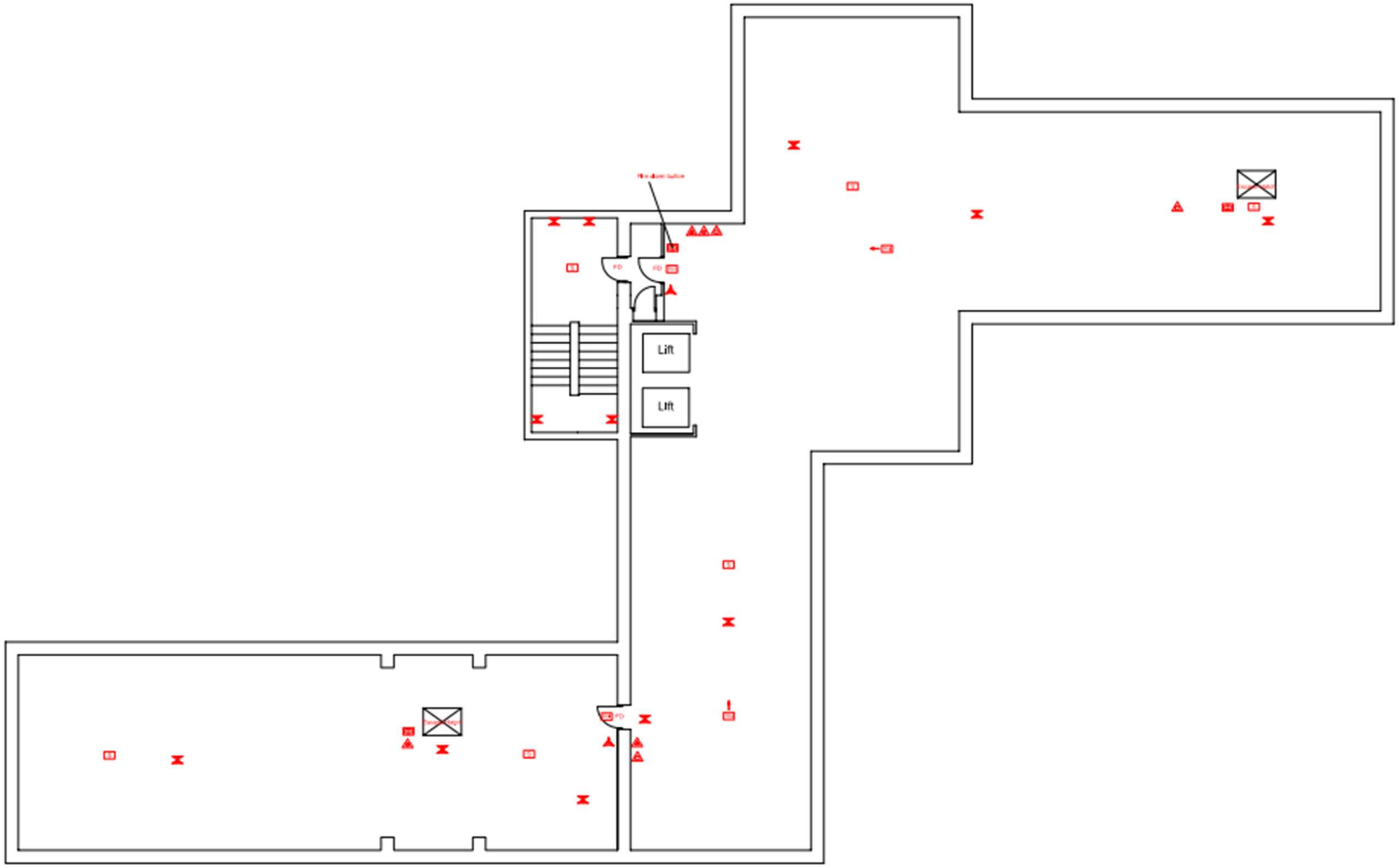
New Building Level 1



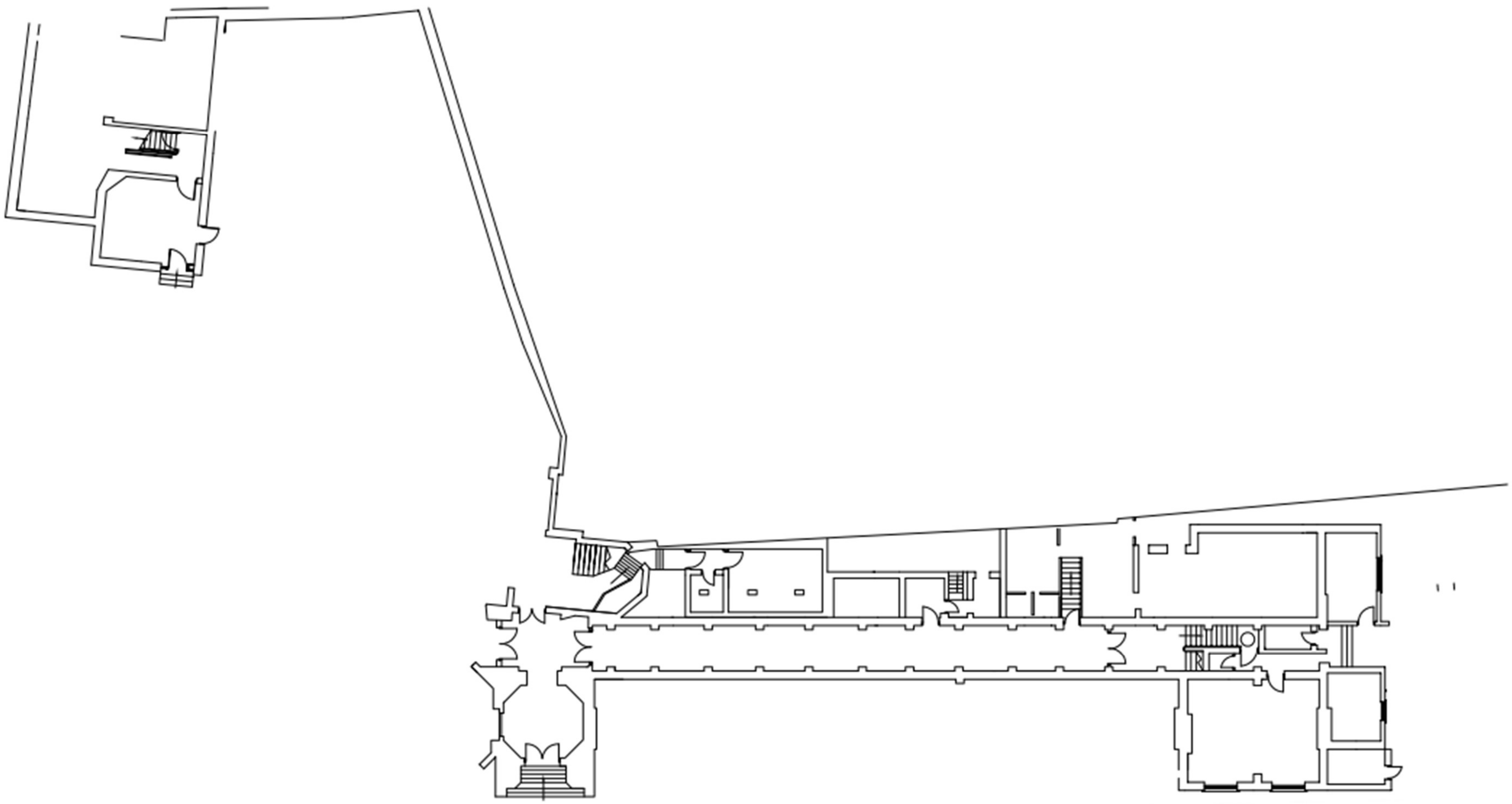
New Building Level 2



New Building Level 3

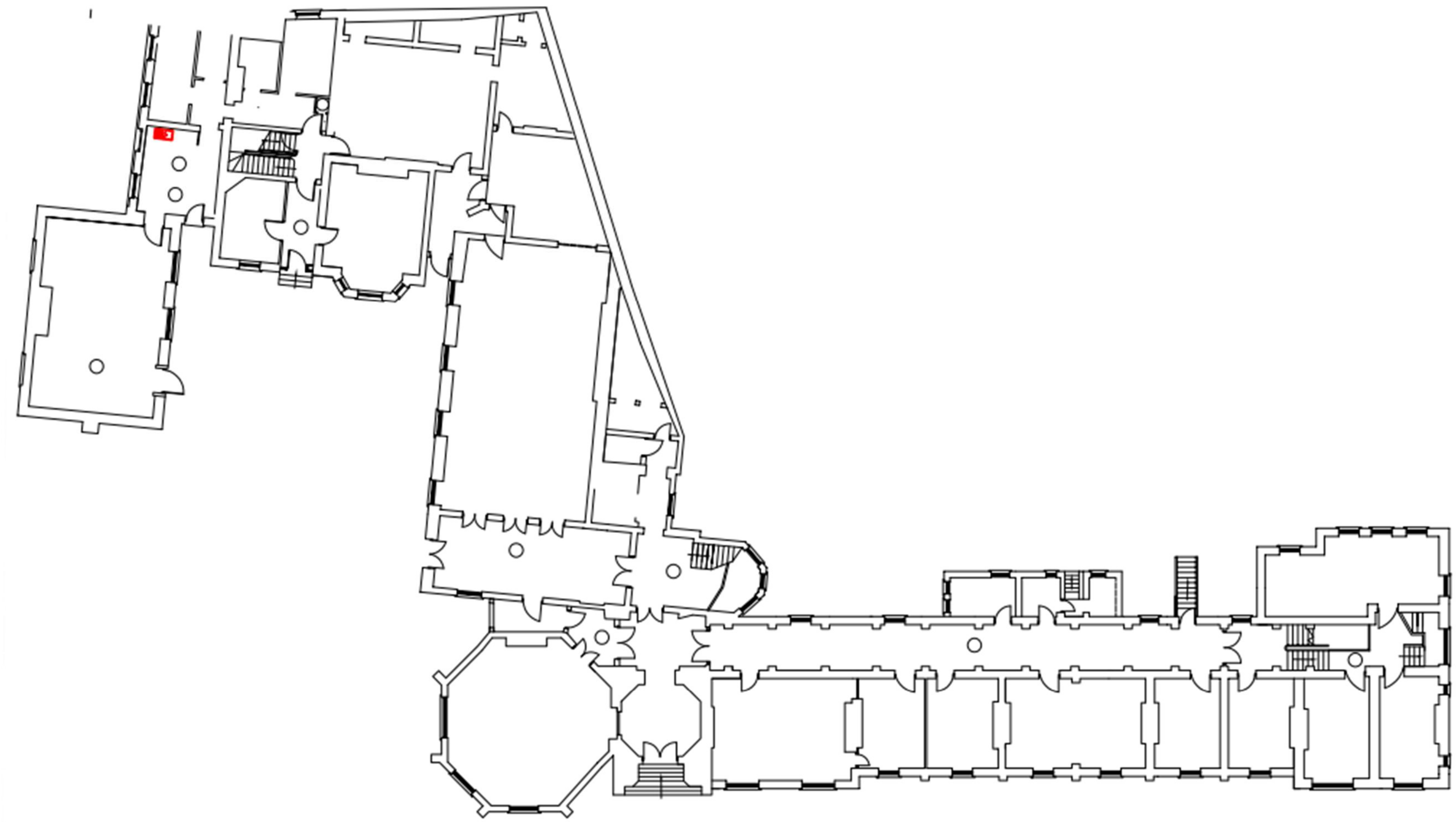


New Building Level 4



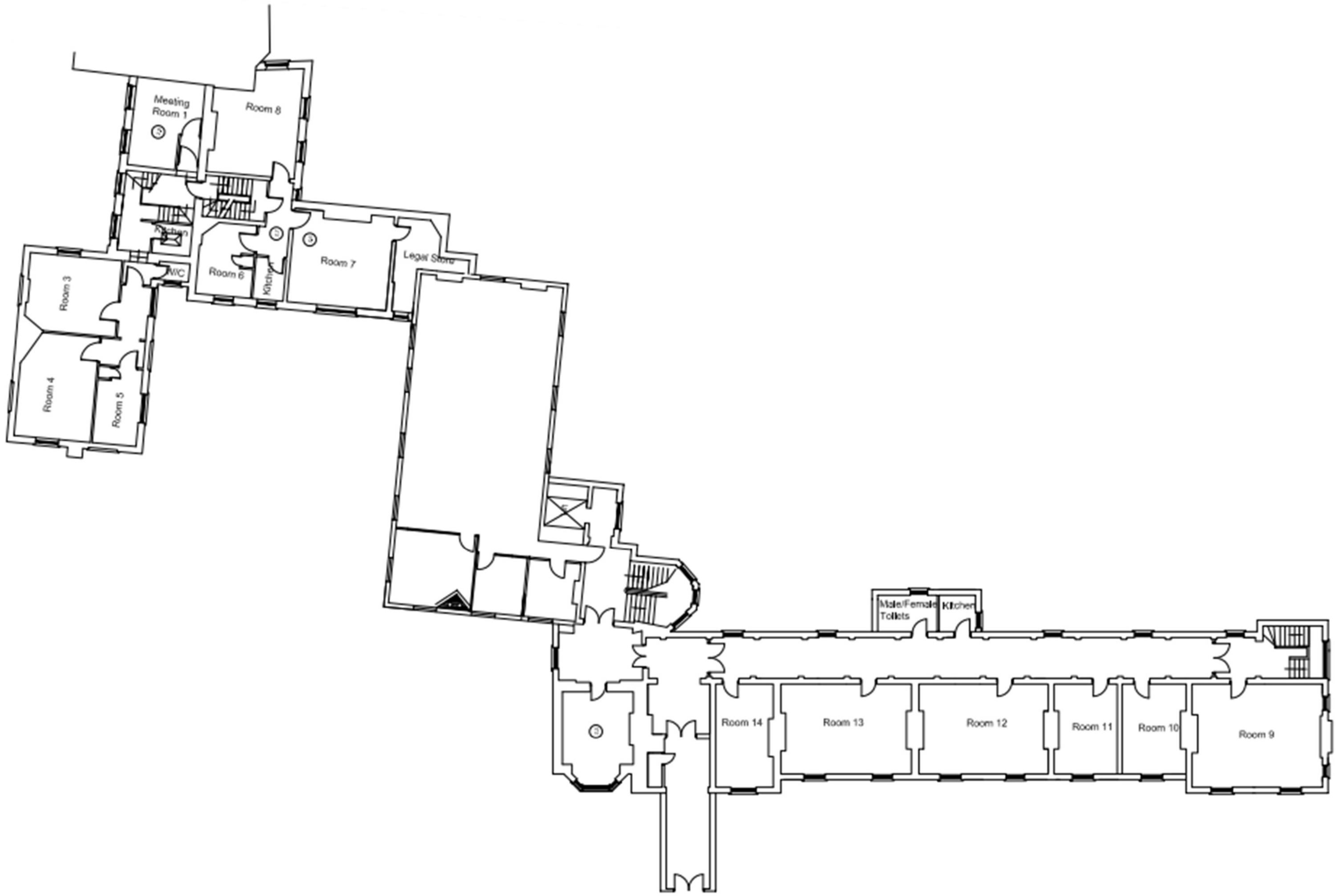
Old Building basement

concept

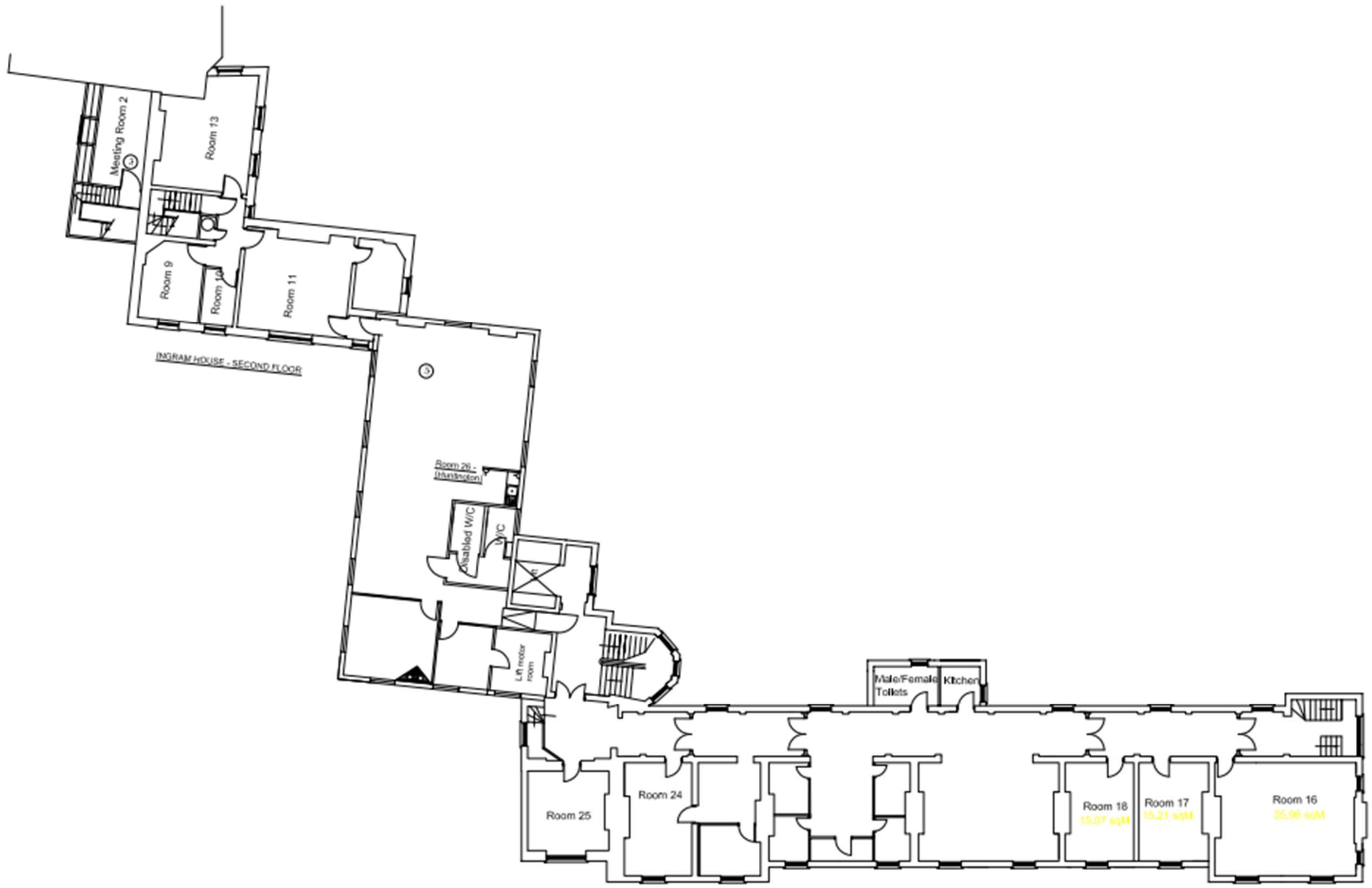


Old Building ground floor

concept



Old Building first floor



Old Building second floor

Appendix B – Financial Analysis Assumptions

Assumption	Value
Discount rate	3.5%
Gas fuel inflation	5%
Elec fuel inflation	5%
Consumer Price Index (CPI) Inflation	5%
Gas unit rate, £/kWh	0.119
Electricity unit rate, £/kWh	0.328
Wood pellets unit rate, £/tonne	400
ASHP seasonal efficiency	300%
GSHP seasonal efficiency	400%
WSHP seasonal efficiency	400%
Direct electric heating seasonal efficiency	100%
Biomass boiler seasonal efficiency	85%

Appendix C – Summary of Direct Emissions Savings for PSDS

The following table presents the fossil fuel only savings for each modelled heating option, for the purposes of the PSDS calculation against the Carbon Cost Threshold (CCT). The existing system figure is based on modelling after implementation of all other efficiency measures.

Note that all options displace the same existing gas loads and therefore gas savings are the same. Only indirect emissions from grid electricity consumption are different for these measures.

New Building:

Option	Annual Gas Consumption, kWh	Annual Gas Saving, kWh	Gas only CO_2 saving, $kgCO_2/yr$
Existing system after energy efficiency measures.	279,607	-	-
Option 1 - ASHP	0	279,607	51,039
Option 2 - GSHP	0	279,607	51,039
Option 3 - WSHP	0	279,607	51,039
Option 4 - Direct electric heating	0	279,607	51,039
Option 5 - Biomass boiler	0	279,607	51,039

Old Building:

Option	Annual Gas Consumption, kWh	Annual Gas Saving, kWh	Gas only CO_2 saving, $kgCO_2/yr$
Existing system after energy efficiency measures.	86,715	-	-
Option 1 - ASHP	0	86,715	15,829
Option 2 - Direct electric heating	0	86,715	15,829
Option 3 - Biomass boiler	0	86,715	15,829