HOARE LEA

Phase 2 - Low Carbon Skills Fund - Salix Applications. Plymouth.
University of Plymouth.

MEP ENGINEERING
HEAT DECARBONISATION PLAN

REVISION P05 – 31 MARCH 2022

Audit sheet.

Rev.	Date	Description of change / purpose of issue	Prepared	Reviewed	Authorised
P01	13/03/2022	Draft plan for initial client review and comment	CW / JW	TS	TS
P02	25/03/2022	Final issue of report	CW / JW / MS	TS	TS
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P04	30/03/2022	Correction of units	CW / JW / MS	TS	TS
P05	31/03/2022	Incorporating client's comments	CW / JW / MS	TS	TS

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Executive summary

University of Plymouth declared a climate emergency in 2019 and subsequently commit to achieve net zero emissions across its estate and operations by 2025, five years earlier than Plymouth City Council. A Carbon Management Plan (CMP) has been produced that sets out the steps the University will make to achieve this 2025 target.

Hoare Lea have been appointed to generate a Heat Decarbonisation Plan (HDP) for the following buildings on the main campus:

- Davy Building
- Link Building
- Smeaton Building
- Scott Building
- Marine Building
- The House

The purpose of the HDP is to provide a clear roadmap to decarbonisation as well as costed, detailed assessments for future funding and budget bids.

The HDP is required to take a 'whole building' approach to the decarbonisation of heating, considering all factors that contribute to the building's energy consumption in order to identify the most cost effective way to achieve decarbonisation.

Potential decarbonisation measures that have been considered within this assessment include:

- Potential Improvements to the building envelope.
- Optimisation and potential replacement of HVAC systems.
- Optimisation and potential replacement of domestic hot water generation plant.
- New/additional/replacement heat pump integration.
- Heat/coolth recovery improvement or integration.
- Waste heat recovery integration and/or improvements.
- Implementation of 'smart' zone controls to minimise energy consumption (e.g., opportunities automatically control lighting and HVAC systems based on actual Occupancy).
- Electric motors, pumps, drives and fans efficiency improvement.
- Lighting and associated controls (internal and external) energy efficiency improvements.
- Improved automatic/BMS controls.
- Pipework and fitting insulation improvements.
- Renewable energy generation (heat and power) integration and/or improvements.

The HDP is required to provide a route map of enabling works and measures that will enable the implementation of low carbon heating solutions in the most cost effective way possible.

The approach that Hoare Lea have adopted with regards to generating the HDP in its entirety is split down into distinct phases.

The first phase of the works is summarised below:

- Review of existing building usage and thermal envelope performance, informed by desktop reviews and site surveys.
- Review of existing MEP services/systems, informed by desktop reviews, site surveys and liaison with the University.
- Review of existing gas and electricity meter data and carbon footprint assessment.
- Benchmarking existing carbon footprint against recognised industry standards/targets.
- Identification of any recommended future additional metering and sub-metering opportunities.
- Outline assessment for potential building envelope decarbonisation intervention measures

The report serves as a consultative document, which, when signed off by University of Plymouth, will form the basis for which the next stage of the HDP development.

The primary recommendation of this report is to fully remove gas fired plant serving all six buildings that are the focus of this report. The gas fired plant is to be replaced with high temperature air source heat pumps to serve a district heating network for all size buildings. This intervention alone will generate significant reduction in carbon emissions but it is recommended that other key interventions are also adopted, as below

- Improve building fabric performance
- Improve glazing thermal performance by provision of secondary or double glazing
- Provision of enhanced or new BMS controls
- Installation of air source heat pumps to generate domestic hot water
- Provision of PV

This report includes recommended next steps to progress the University's decarbonisation agenda, including

- Undertaking further site wide optimisation projects to reduce demand
- Provision of enhanced metering to inform further development of recommended decarbonisation interventions
- Development of detailed metering strategy
- Establish measurement and verification plan to monitor decarbonisation interventions
- Undertake detailed assessment of domestic hot water usage throughout all buildings to inform decarbonisation approach
- Undertake detailed load analysis of the existing heat network and develop concept design to replace gas fired plant with air source heat pumps
- Review future projects and phasing of heat decarbonisation plans with other planned project work to minimise disruption
- Assess combined effect of multiple interventions taken together – including feasibility and total carbon reduction

1. Brief

1.1 Overview

The University of Plymouth have committed to reducing their carbon emissions and their negative impact on the environment. By signing up to the Climate Emergency in 2019, their ambitious target is to achieve net zero emissions (from scope 1 and 2) by 2025, and net zero for scope 3 items by 2030 - 2050.

The University have produced a Carbon Management Plan (CMP), which sets out the steps the University will take to achieve these 2025 and 2050 targets. The plan outlines the five key elements to achieve the targets of the carbon reduction plan, which are;

- Improving space utilisation
- Carbon reduction projects
- Fuel and power conversion
- Institutional change
- Behaviour change

Government funding has been – and remains – critical to achieving the 2025 target. This includes funding from Salix's Public Sector Decarbonisation Scheme (PSDS), which the University has obtained previous funding with which to undertake other carbon reduction measures on the campus.

Another key funding stream is the Salix Revolving Loan Fund, which has resulted in an annual CO_2 saving of c.2,000 tCO_2/year since its inception. The fund is undergoing a revision and shift the focus from energy efficiency to the decarbonisation of heat.

The CMP identified the need for the University to produce a Heat Decarbonisation Plan (HDP) for large emitting sites / buildings.

Hoare Lea have been appointed by University of Plymouth to assist with the production of an HDP to RIBA Stage 1 for the following 6 No. buildings located on the main campus within Plymouth city centre:

1. Davy Building
2. Link Building
3. Smeaton Building
4. Scott Building
5. Marine Building
6. The House

The purpose of a HDP is to provide a clear roadmap to decarbonisation as well as costed, detailed assessments for future funding and budget bids.

1.2 Key Requirements of the HDP

The HDP is required to take a 'whole building' approach to the decarbonisation of heating, considering all factors that contribute to the building's energy consumption in order to identify the most cost effective way to achieve decarbonisation. The HDP is required to address the following points:

a) Current energy use in each building
b) Potential building fabric improvements to reduce the size of low carbon heating plant and energy bills.
c) Potential measures to reduce the peak electrical consumption of each building in order to avoid or reduce the need for large upgrades of the electrical infrastructure.
d) Identify potential eligible technologies for funding streams such as the Public Sector Decarbonisation Scheme, or other Salix funds.
e) The specific measures needed over what timescale to fully replace fossil fuel reliant systems with low carbon alternatives (e.g., heat pumps or other approaches).
f) The estimated cost to reduce a tonne of carbon (CO2e) over the lifetime of the project, using Salix Revolving Loan updated guidance. The HDP is required to identify how technologies could be combined to reduce as far as possible the cost per tonne of carbon over the lifetime of the project.
g) The outcomes in terms of carbon emissions reduction and projected energy bill changes.
h) The full costs of the works, including any anticipated enabling works.
i) A detailed assessment of each building using surveys to consider potential challenges, consents needed and any other issues.

The HDP is intended to provide a route map of enabling works and measures that will enable the implementation of low carbon heating solutions in the most cost effective way possible. The report includes:

a) Scope and introduction
b) Baseline status: informed by half hourly data provided by University of Plymouth, the energy profile, overview of metering arrangements, heating and electrical demand, existing heating technologies in the building, and current building fabric and associated heat loss characteristics.
c) Current and pipeline works assessment: identify how this will impact the decarbonisation of the building.
d) Site assessment: including issues such as planning restrictions that might limit options for the site and potential solutions or planned changes to building usage.
e) Opportunities: technical assessment of heat and electrical decarbonisation opportunities and modelling of impact (using half hourly data) on the emissions profile of the building and energy bills pre and post implementation.
f) Plan / route map to decarbonisation: outline of fully costed viable options, informed by site surveys, details of site-specific challenges, enabling works, and cost of carbon calculations for compliance with Salix funded schemes.

The Heat Decarbonisation Plan must:

a) Use half hourly data sets to model actual heat loads with heat pumps to access their sizing and the electrical capacity requirements.
b) Provide a realistic, costed options appraisal for the decarbonisation of each specific building using a combination of technologies.
c) Use site surveys to identify building-specific, and potentially derailing, issues associated with particular solutions for the sites.
d) Complete RIBA Stage 1, so that the University is able to proceed to the next RIBA stages depending on further funding availability.

2. Introduction

Hoare Lea have been appointed by University of Plymouth to develop a Heat Decarbonisation Plan, to submit as part of the Salix Phase 2 Public Sector Low Carbon Skills Fund (LCSF).

2.1 University of Plymouth synopsis

University of Plymouth is a public research university, predominantly located within Plymouth, Devon, but who are affiliated with other campuses and affiliated colleges across the southwest.

The main campus, located in the heart of Plymouth, represents their core, and offers a range of teaching, research, office and social spaces that support over 18,000 students, and over 2,500 staff. The main campus is approximately 100,000m^2, and is indicated in the below image.

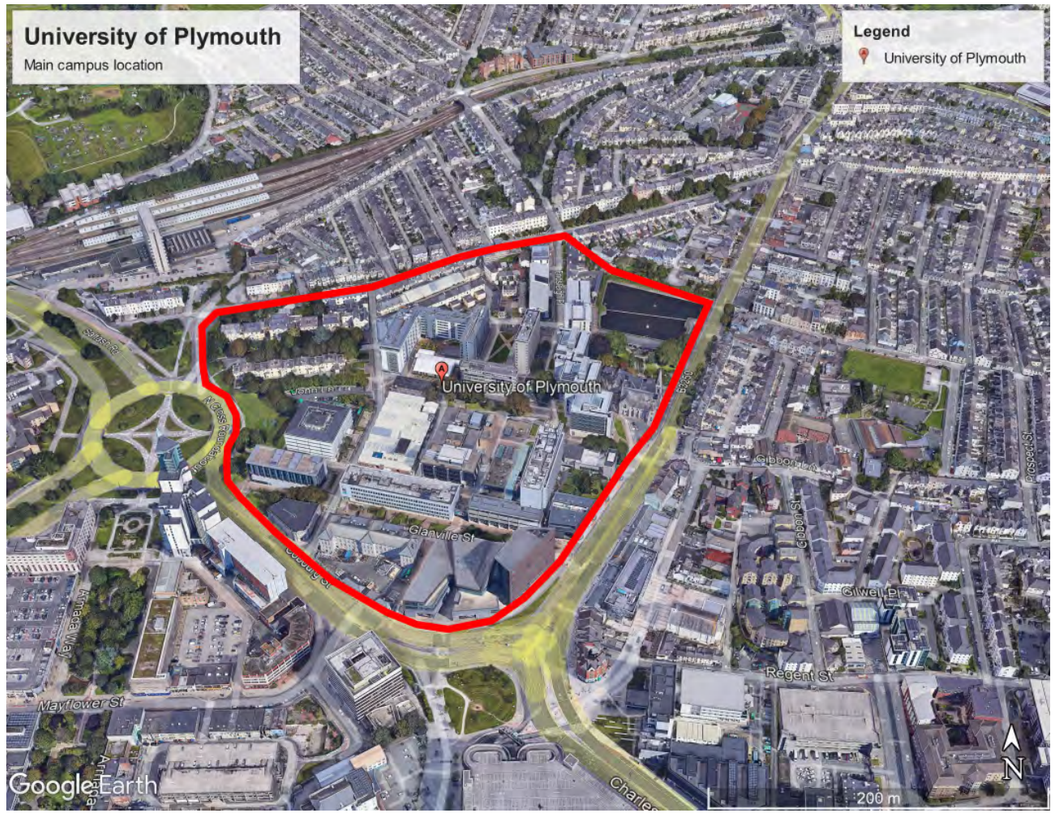


Figure 1 - Approximate extent of University of Plymouth's main campus

The building stock on the main campus range in size and age from 100+ year old domestic houses, to large, multi-storey iconic buildings less than 10 years old, along with everything in between.

2.1.1 University's carbon policy

The University have committed to reducing their carbon emissions and their negative impact on the environment. By signing up to the Climate Emergency in 2019, their ambitious target is to achieve net zero emissions (from scope 1 and 2) by 2025.

Scope 1 & 2 emissions make up 30% of the University's total emissions, with indirect scope 3 emissions making up the majority at 70%. The majority of the source of scope 1 is gas use, with the remainder of the emissions being feet vehicles and refrigerant gases. Scope 2 emissions is made up of electricity purchased from the grid.

The University's Carbon Management Plan (CMP) sets out the steps the University will take to achieve this 2025 target. The plan outlines the five key elements to achieve the targets of the carbon reduction plan, which are;

- Improving space utilisation
- Carbon reduction projects
- Fuel and power conversion
- Institutional change
- Behaviour change

2.1.1.1 Emissions History

The University has reduced its carbon emissions to date by 48% from the base year 1990. The biggest impact in emissions reduction was seen between 1990 and 2008, where the easiest to impact projects were carried out. Since 2008, emissions overall have reduced, but there has been periods of increase, as targeting reduction increasingly involves more complex solutions.

The University is currently on target for the Department for Business, Energy & Industrial Strategy (BEIS) emissions reduction pledge 2020 target of 30% reduction by 2020/21 for public and higher education sectors in England. The University was also ahead of the Governments former target of an 80% reduction in CO2e emissions by 2050, now replaced with the net zero target by 2050. Projecting forward the University's scope 1 & 2 emissions will be drastically reduced through purchasing a renewable tariff for heat and power (current proposal to switch to renewable electricity in 2021/22 and green gas in 2025).

2.1.1.2 Carbon projections

In reviewing the current carbon action plan, the following chart shows the projected carbon emissions and gas and electrical usage and identify any current delivery gap. The net zero carbon (scope 1 & 2 emissions by 2025) target delivery is largely identified, with a saving of 64 TCO2e needing to be identified going forward. This gap is due to needing to identify electric van alternatives to the current larger waste vehicles in use, and to identify options for moving to alternative gases that are classified as having ultra-low Global Warming Potential (GWP) in our refrigerant equipment.

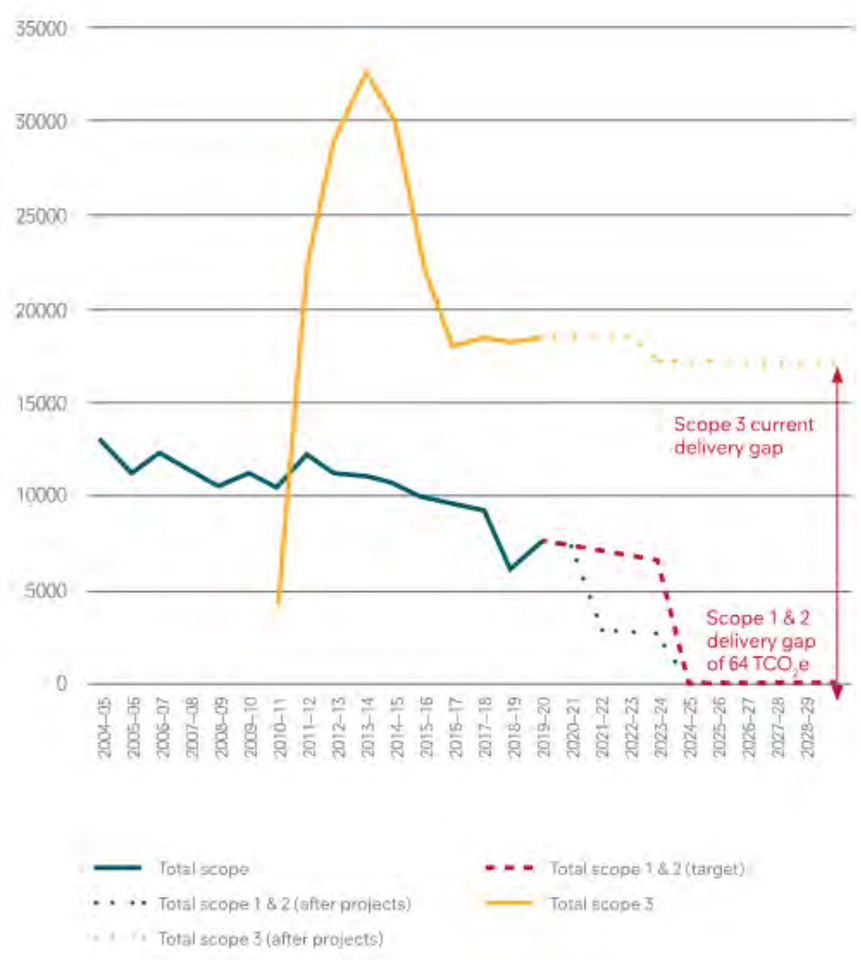


Figure 2 - UoP's total historic emissions and forecast

2.1.1.3 Energy Projections

Running alongside the net zero carbon target (to be delivered through fuel conversion projects) is the target to continue to reduce energy use; gas use by 25% and electricity use by 20% by 2030 (based on 2005/06 levels). This is an ambitious target going forward, especially as we are planning for a large shift in our base energy use over the coming years. It is expected that gas use will initially increase as we increase operation of the existing gas led CHP to maximise electrical generation. Following that, we are in the feasibility stage of an ambitious and longer term project to convert our gas led district heating system to an electrically led, low temperature ambient heating and cooling loop. Meaning that over time gas use will begin to come down and electricity use will increase as buildings are converted to be electrically heated.

The following chart shows the forecast gas and electricity use based on expected energy use after planned projects, additional estimated savings from unidentified projects and the impact of the energy infrastructure project. This shows that the gas target is likely to be met, but the electricity use increase is currently a challenge to delivering the target savings. Further electricity reduction and generation projects are needed to be identified going forward.

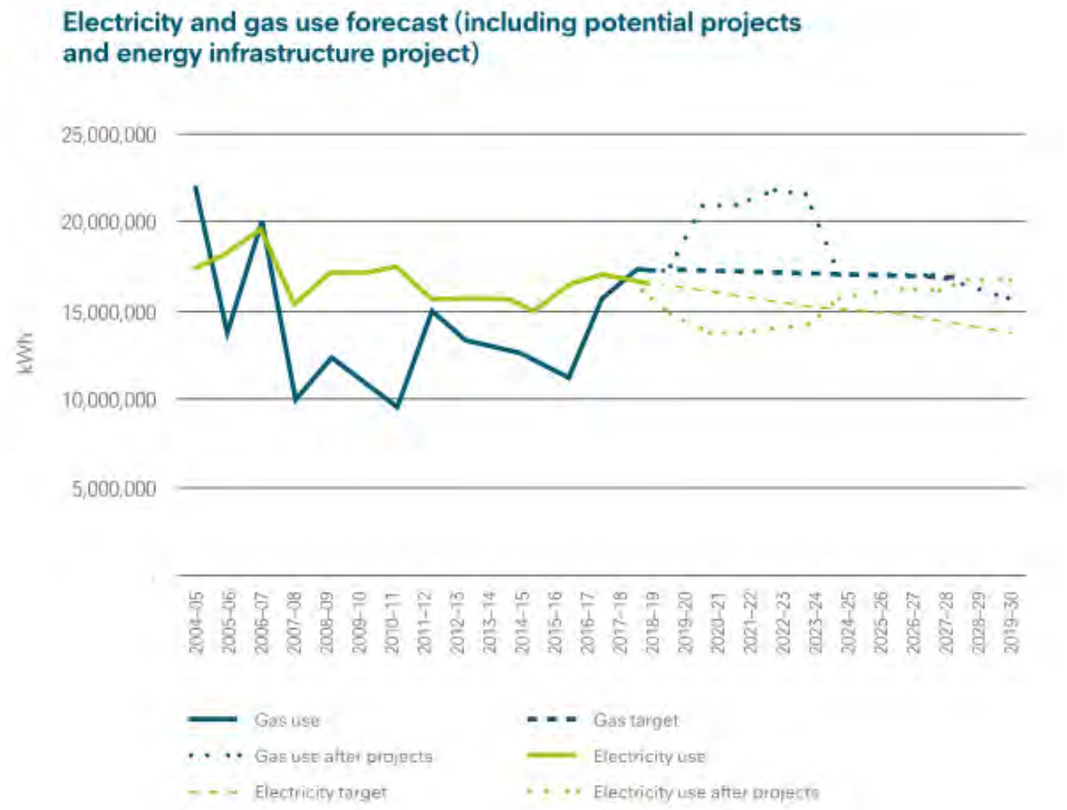


Figure 3 - Electricity and gas use forecast

2.2 Purpose of this heat decarbonisation plan

The plan has been commissioned by University of Plymouth to specifically help define a set of viable strategies and measures to be implemented on the Estate, to achieve best value with regards to methods of reducing carbon emissions of the existing building stock. This will provide tangible set actions that will assist the University in delivering against their ambitious carbon policy, to become net zero by 2030.

These buildings were selected for a number of reasons, as set out later in this report, but principally they form the heart of the campus, and represent the buildings with the highest heating intensity / energy usage.

2.3 Related Policy and Drivers

2.3.1 National drivers

Approved Document Part L

Part L of the Building Regulations is the mechanism by which government is driving reductions in the regulated CO2 emissions from new buildings.

Current requirements: Part L 2013

Part L has five key criteria which must be satisfied as follows:

a) Criterion 1 - Achieving the Target Emission Rate (TER)
b) Criterion 2 - Limits on design flexibility
c) Criterion 3 - Limiting the effects of solar gains in summer
d) Criterion 4 - Building performance consistent with the Building Emission Rate (BER)
e) Criterion 5 - Provision for energy efficient operation of the building

Criterion 1 requires that the building as designed is not predicted to generate CO_2 emissions in excess of that set by the Target Emission Rate (TER) calculated in accordance with the approved Standard Assessment Procedure (SAP) 2013.

Criterion 2 places upper limits on the efficiency of controlled fittings and services; for example, an upper limit to an external wall U-value of 0.35W/m^2.K (non-domestic buildings).

Part L 2021 regulation changes

Updated Part L Building Regulations published in October 2021 are set to come into force June 2022. Works that are carried out from the enforcement date will need to be assessed under these new regulations (i.e., where meaningful progress has not commenced on site by implementation date).

The formal calculation methodology and associated software for this version of Building Regulations has not yet been issued (as of 24th February 2022) and therefore, the implications of the identified decarbonisation measures documented in this report against the forthcoming Building Regulations compliance cannot be appraised at this stage.

2.3.2 Local drivers

2.3.2.1 Plymouth Council

Tackling climate change is one of the Council's top priorities and so in March 2019 they declared a Climate Emergency and pledged to make Plymouth carbon neutral by 2030.

This is a big challenge and huge changes are needed to be made so they have produced two actions plans to show what they intend to do.

The Climate Emergency Action Plan (CEAP) lists all the actions that the council are taking, as well as other partners in the Plymouth Net Zero Partnership, to reduce emissions across the city and to encourage others to do the same.

The City Council's emissions make up about 1% of the city's overall greenhouse gas emissions. These are going down every year but more needs to be done, more quickly, to reduce them further. The Corporate Carbon Reduction Plan (CCRP) lists the things they will do to reduce emissions in the day-to-day running of the Council, for example in their own buildings and fleet.

The council monitor their progress against each action and review the plans in a public forum every 6 months. They will develop new action plans each year up to 2030.

As part of the Plymouth Climate Emergency Action Plan (2022), it is declared that *'The University of Plymouth will continue to deliver energy reduction projects (and work towards reducing mains grid electricity use by 20% and mains gas by 25% as a minimum by 2030 from 2005/06 levels) including: remaining LED lighting conversion projects; smart building management system upgrades for advanced controls; transformer replacements; big data project, using data driven analytics to reduce energy use.'*

2.3.3 Plymouth City Council's District Energy Network

Plymouth City Council have identified that in order to play their part in the action against climate change, Plymouth has committed to becoming a carbon neutral city. The development of a District Energy Network will be the key to achieving this goal by providing local businesses and housing with heat and power from more sustainable sources.

A City-Wide Strategy for District Energy was produced in 2017 and identifies District Energy Opportunity Areas, where this should form a key part of new development proposals. As can be seen in Figure 4, the Low Temperature Building Zone extends to the periphery of University of Plymouth's campus, and is ultimately intended to extend to cover the whole of Plymouth.

All developments within the Low Temperature Building Zone need to be designed around a low temperature heating system wherever possible, in line with the 5th generation network connections packs.

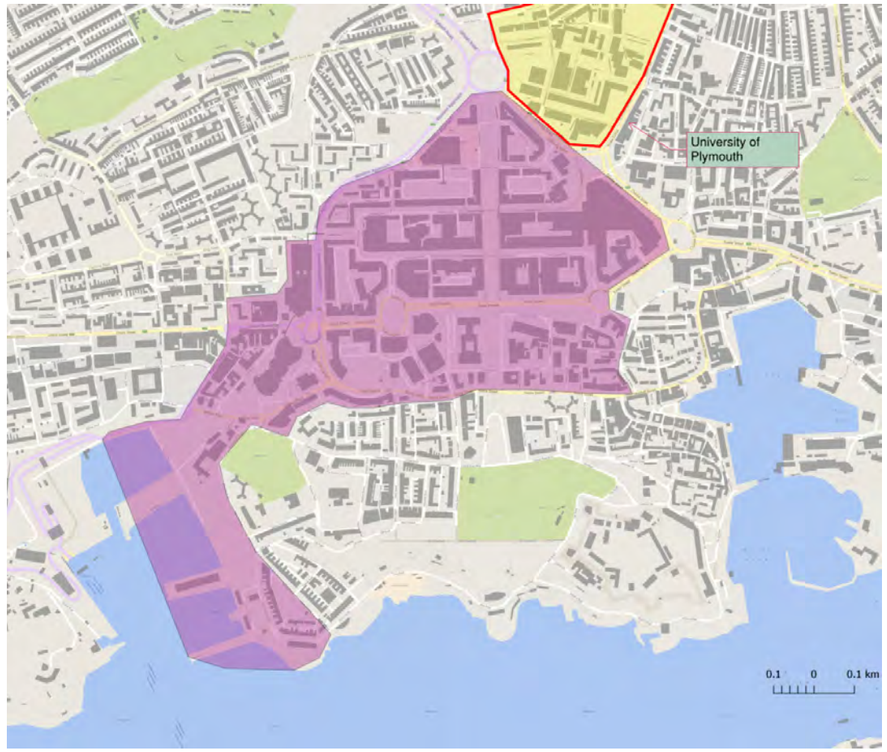


Figure 4 - Low Temperature Building Zone

2.4 Heat Decarbonisation

The introduction of electrically-driven heat pumps will enable University of Plymouth to reduce its reliance on fossil fuel consuming heating systems, resulting in significantly decarbonised heating systems.

The table below provides a high-level overview of the various heat pump technologies that can potentially be adopted:

Table 1 - Comparison of Heat Pump Technologies

	**Ground source heat pumps** Ground Source systems work to extract heat or cooling energy from the ground. They are generally slightly more efficient than air source systems, as the ground temperature is more stable over the course of the year relative to air temperature. There are four common varieties of ground source systems: – Vertical, open loop, direct cooling (i.e. without heat pump) – Vertical, open loop, with heat pump – Horizontal, closed loop, with heat pump – Vertical, closed loop, with heat pump
	**Water source heat pumps** Water source heat pumps use bodies of water, such as rivers, lakes, or oceans to provide heating or cooling energy to a building.
	**Air source heat pumps** Air source heat pumps (ASHP) use thermodynamic principles to convert heat from the air into useable heat within the building. Unlike some other sources of renewable energy, heat pumps do require energy (typically electricity or gas) to pump and compress refrigerant through the system. However, under the Renewable Energy Directive 2009/28/EC they are classified as renewable technologies provided that the final energy output significantly exceeds the primary energy input required to drive the heat pump. ASHP need to be located externally with access to the ambient air, typically at ground level (within a suitable enclosure where necessary) or at roof level.

2.5 Grid Decarbonisation.

2.5.1 Historic progress

The carbon factor of the National Grid – the amount of carbon dioxide released per kilowatt hour of electricity generated and distributed – is recognised in current Building Regulations as being 0.519 gCO_2/kWh. However, the national mix of electricity generation methods is progressing towards greener solutions with renewable sources accounting for 33.4% of the electricity generated in the UK in 2018; up from 24.4% in 2016 (Ofgem). According to government statistics, it is understood this figure had risen to 43% of the UK's electrical generation in 2020 having been made available through renewable means, demonstrating a further significant step.

As a consequence, the Building Regulations Part L 2013 value of the National Grid carbon factor has been shown to be substantially higher than how the grid is performing in reality. This severely impacts the calculated emissions produced by all heat raising plant that use electricity directly or generate it to offset other emissions. The graph below shows how the mix of generation techniques serving the National Grid, as well as the associated carbon factor, has varied over the past seven years – encouragingly, the carbon intensity of the grid has reduced to almost a third of its value in 2012 – just 0.177 $kgCO_2$/kWh (BEIS). The carbon emissions associated with electricity consumption are therefore much lower than reported in Building Regulations. This means that under the Part L 2013 methodology the CO_2 emissions associated with electrically-driven plant are being overestimated by over 200%.

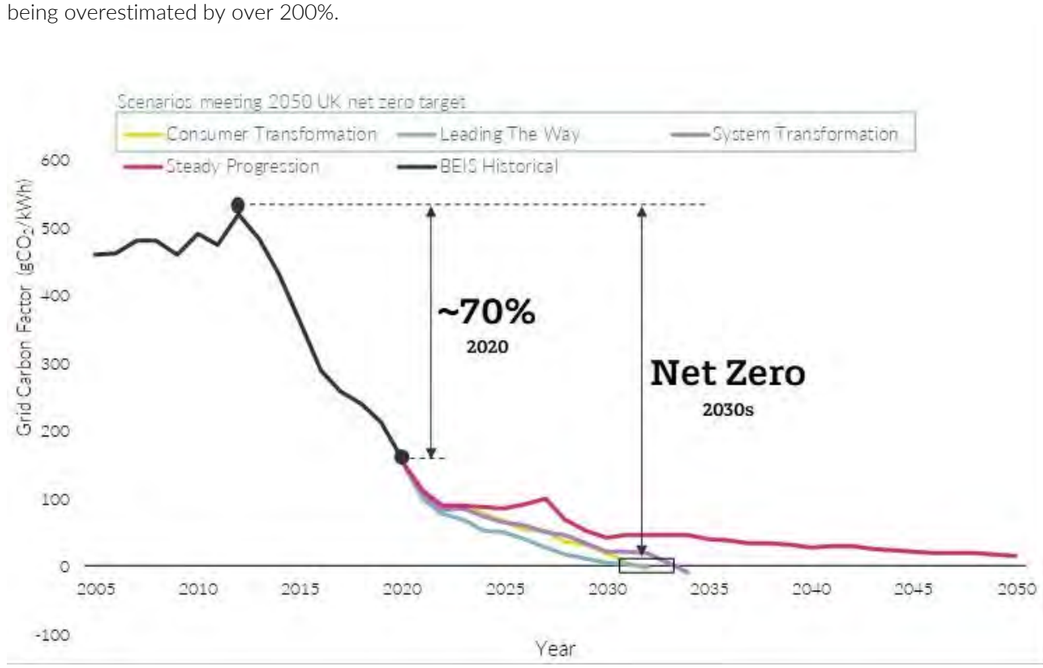


Figure 5 - Scenarios meeting 2050 UK net-zero target

2.5.2 Future projections

The Future Energy Scenarios (FES) document, produced by the National Grid, discusses how the UK's energy landscape is changing. This year's report, FES 2020, makes projections of how the mix of generation in the grid is likely to change between now and 2050 – the year by which the Climate Change Act 2008 set the target of reducing the UK's CO_2 emissions by 80% from 1990 levels. This target has now been revised to be Net Zero in light of the Committee on Climate Change's recent report and the declaration of a Climate Emergency.

FES discusses these projections in one of four scenarios and the graph above combines these future trajectories with the actual carbon intensity of the National Grid. The reported emissions associated with electricity generation have fallen steeply since 2012 and in all cases, the FES 2020 scenarios see the carbon factor of electricity fall below 100 gCO_2/kWh by 2035.

Based on the above projection, the adoption of heat pump technologies will result in the continuing decarbonisation year on year.

3. Heat Decarbonisation Plan Methodology

3.1 Scope

A 'whole building' approach to the decarbonisation of each building will be taken, considering factors that contribute to the building's 'operational' energy consumption in order to identify the cost-effective ways to achieve decarbonisation.

Our approach will be in line with the principles outlined in PAS 2038:2021 'Retrofitting non-domestic buildings for improved energy efficiency – Specification', and will follow the following five step hierarchy to achieving net zero carbon outlined within the UK Green Building Council's (UKGBC) framework:

1. Measure energy consumption
2. Reduce energy consumption
3. Install on-site renewable energies
4. Purchase offsite renewables
5. Offset any remaining emissions

It is highlighted that the commissioned works do not include any embodied carbon assessment works (either 'in use' or 'in construction'), nor do they include the assessment or identification of any measures necessary to achieve operational net zero carbon (i.e. steps 4 and 5 in the above hierarchy).

3.2 Strategy

The initial phase of works was to undertake surveys of the 6 No. buildings, and to review record information as was available, in order to gain a high level understanding of the construction, building usage and mechanical, electrical, and public health (MEP) services and systems of each building.

Requested documentation included:

a) documentation relating to the age, construction and usage of the buildings, and any protected statuses,
b) details relating to the incoming electricity supply infrastructure, including agreed peak capacity
c) at least 12 months of utilities half-hourly meter readings (pre-pandemic) and associated unit costs
d) details of the heating, ventilation, and air conditioning (HVAC) systems
e) details of any existing low or zero carbon technologies
f) details of draft revised Salix Revolving Loan Fund terms, including advice on eligible technologies.
g) details of any future proposals that are required to be considered within this body of works.

In addition to the above, the following documentation was also deemed to be beneficial where available:

a) any recent ESOS (Energy Saving Opportunities Scheme) reports
b) relevant asset registers
c) existing plant/equipment maintenance records, including any planned preventative maintenance records
d) plant/system replacement strategy documentation

3.3 Meter Data Analysis and Benchmarking

University of Plymouth provided our engineering staff access to their online Energy Management Software (C3ntinel), which captures all of the primary gas and electricity utility meters, as well as some further sub-metering and heat metering within some of the buildings.

The metering data captured through this platform can be interrogated down to a resolution of minutes, thus providing a very clear understanding of the various utility loadings within each of the buildings. For the purpose of this reporting, we have taken half-hourly data as our benchmark to measure against, as this provide sufficient granularity for this stage.

Analysing this platform's data has allowed us to obtain a clear understanding of the existing energy profiles of each building, and to establish peak demand and annual consumption figures.

Following a review of the metering data provided, we have identified a number of potential beneficial additional sub-metering opportunities, as well as some anomalies in the meter readings that we would recommend the University investigate further, as outlined below;

- It is recommended that all buildings are sub-metered, per floor or by appropriate building zone, to accurately measure the energy consumption of specific areas.
- Electrical and heat sub-metering of individual HVAC equipment for each building, to ascertain the level of consumption for each plant equipment, which will allow for suggested optimisation of systems/controls to reduce energy consumption.
- Investigate the anomalies in the electricity metering of The House, as significantly large, instantaneous half-hourly spikes of usage are affecting the quality and accuracy of the of the data.
- Ensure that any new, and existing meters, are equipped with data loggers with an appropriate amount of storage to store and review historic meter data, at is understood that the vast majority of heat meter data for the Marine Building is lost due to an issue with logging data storage due to a BST time zone change in 2021. It is also recommended to further investigate the cause of this issue; and to take steps to prevent this from occurring in the future.
- Investigate issues regarding BMS PCs not obtaining readings from the metering system, and maintain high accuracy and resolution of meter data gathering.
- Investigate issues regarding heat metering for The House, as sub-meters for individual UFH zones, additionally the office, hot water system and AHU1 seem inaccurate and with missing data.

The utility metering data provided was utilised to identify the existing carbon footprint of each building, which was benchmarked against industry recognised standards, with this assessment utilised as the baseline to assess potential decarbonisation measures identified through this study.

3.4 Site Surveys

Visual, non-intrusive site surveys were carried out within each building which were primarily focused on decarbonising the heating and cooling systems. The site surveys facilitated validating the key information obtained through the record documentation review process, reviewing the performance of the building envelope, assessing the age and apparent condition of the existing MEP services systems, and exploring potential decarbonisation opportunities.

Where planned preventative maintenance/plant replacement schedules were not made available, the site surveys assisted with establishing the current age and perceived condition of the existing relevant MEP systems (i.e., plant/equipment, distribution infrastructure and controls).

The surveys also assisted with identifying any carbon related end of life systems and whether any replacement works are deemed necessary or recommended as part of any of the identified decarbonisation measures.

3.5 Basis of Technical Assessment

The site surveys, together with desktop studies and technical assessments, enabled the team to establish a robust schedule of energy saving measures in order to decarbonise each building, which included identifying measures to reduce reliance on fossil fuels. Decarbonisation intervention measures considered included:

- Potential Improvements to the building envelope.
- Optimisation and potential replacement of HVAC systems.
- Optimisation and potential replacement of domestic hot water generation plant.
- New/additional/replacement heat pump integration.
- Heat/coolth recovery improvement or integration.
- Waste heat recovery integration and/or improvements.
- Implementation of 'smart' zone controls to minimise energy consumption (e.g., opportunities automatically control lighting and HVAC systems based on actual Occupancy).
- Electric motors, pumps, drives and fans efficiency improvement.

- Lighting and associated controls (internal and external) energy efficiency improvements.
- Improved automatic/BMS controls.
- Pipework and fitting insulation improvements.
- Renewable energy generation (heat and power) integration and/or improvements.

As part of this assessment, potential restrictions and constraints that may restrict the provision of any potential energy saving measures or the application of any new low carbon technologies have been considered.

3.6 Fabric first

Where opportunities exist, a fabric first approach has been taken in order to establish potential options to minimise the energy consumption and carbon emissions of each building, to reduce the size of any new low carbon heating plant, and to limit the requirement for any associated electrical supply upgrades (which may be required where heat pumps are introduced).

Opportunities to improve the performance of the building envelope were assessed from a thermal performance only. Potential decarbonisation intervention options considered included improving insulation, provision of replacement or secondary glazing, minimising uncontrolled infiltration and minimising overheating/cooling duties.

A high level assessment of the heat loss of each building has been carried out to assist with evaluating the impact of any potential building envelope improvements works, as well as to assist with any replacement/new preliminary plant sizing. These assessments have been based on estimated heat losses through calculation, and corroborated against the metering data where available.

3.7 Heating and Cooling System Decarbonisation

With specific focus on the heating and any cooling demand of each building, the scope for the application of low or zero carbon technologies has been evaluated, with the subsequent assessment factoring in any proposed energy efficiency improvement measures (e.g., building envelope thermal performance improvement works) in order to minimise demand.

The assessment included the identification of measures to reduce reliance on fossil fuels.

Where the introduction of low carbon technology plant is deemed technically viable, the baseline energy/carbon calculation models will be utilised, in conjunction with relevant half hourly weather data, in order to assist with preliminary plant sizing, with indicative plant selections obtained where deemed beneficial in order to ensure that the assessed impact to the energy / carbon footprint is as accurate as possible.

Full load and part load efficiency data for the indicative heat pump selections will be utilised (where deemed appropriate) to optimise accuracy of the assessment (i.e., by factoring in heat pump part load energy efficiency data into the assessment, to provide site specific seasonal efficiency data compared to standard condition seasonal efficiency data published by heat pump manufacturers).

Initial guidance will also be provided on the optimum configuration in terms of the plant's integration into the existing system/s, to inform design development going forward and the Stage 1 cost plan.

As part of these works, an appraisal will be carried out to establish potential measures to fully replace fossil fuel reliant systems with zero carbon alternatives.

3.8 Electrical Load Assessments

A high level electrical load assessment has been carried out in order to establish whether the proposals will result in a requirement to upgrade the incoming electrical supply capacity (e.g., due to additional electrical consumption associated with the introduction of any new electric low carbon technologies such as heat pumps). Associated electrical upgrade works have been included within the cost estimates.

3.9 Additional Renewable Energy and Low Carbon Technology Integration

The opportunity for new or additional renewable energy and/or low carbon technology opportunities has been assessed for each building (e.g., new or additional photovoltaic panel arrays, thermal stores, etc.).

3.10 Smart Controls

The opportunity to Implement 'smart' zone controls has been assessed in order to minimise energy consumption (e.g., opportunities automatically control lighting and HVAC systems based on actual Occupancy).

3.11 Energy and Carbon Reduction Impact

Using recognised industry assessment methodologies, calculation models and relevant assessment tools, the identified decarbonisation intervention measures have been assessed to establish the estimated impact to the energy consumption of each identified energy efficiency improvement measure, and the resulting impact to the carbon footprint (both individually and cumulatively).

In order demonstrate the value of the intervention

The conclusions drawn from the technical assessment have articulated the potential impact of the identified energy efficiency measure works to the carbon footprint of each building (e.g. cost per kg.CO2 saved), as this will help inform those measures which present greatest value.

3.12 Feasibility Costs

Against each of the technical reviews, a cost estimate has been provided by the Quantity Surveyor (QS) for each building, to provide an outline budget for each of the works items.

Cost estimates include for costs associated with integrating the proposals into the existing systems, including any associated builders work will be made. In addition, any temporary works that may be required have been estimated, although this will require further assessment as the full scope and implications of each of the proposals are defined at later stages.

The feasibility costs have been produced to identify the estimated cost per tonne of carbon saved for each assessed decarbonisation intervention energy saving measure, to provide an informed approach to the various solutions.

Refer to the appendices of this document for the cost breakdown, and all key assumptions made in the development of the costings at this stage.

3.13 Risk and Future Scope Assessment

As part of the assessment for each building, a high level assessment has been carried out to identify any key risks associated with identified potential decarbonisation interventions.

Where appropriate record documentation has been provided, high level desktop studies have been undertaken to assess any ground conditions relevant to new plant areas/enclosures. In addition, underground services routes that may need to be diverted or avoided have been highlighted.

Where identified decarbonisation measures may result in a requirement for a formal planning application (e.g., where building fabric thermal performance improvements are identified, where new external plant is considered, electricity supply upgrade works. etc.), commentary has been provided around any potential planning requirements, possible constraints and considerations, together with the risks of obtaining this, both in terms of consent and timescale.

A high level assessment of the risk and likely cost for any asbestos removal or encapsulation required to facilitate the identified decarbonisation works has been undertaken, with suitable cost allowances captured within the cost reports. The scope of any future asbestos surveys would need to be informed following the development of the proposals; allowances for such works have been identified within the cost reports.

This report also provides commentary on the potential operational implications of the identified decarbonisation interventions.

3.14 Report Structure

This report is presented in the form of a RIBA Stage 1 report, and provides recommendations and anticipated outcomes for proceeding into future design stages. A summary of the proposed report content is provided below:

1) Detailed overview of approach and methodology adopted to generate report.
2) Summary of existing building usage and envelope thermal performance, informed by desktop reviews and site surveys.
3) Summary of existing MEP services/systems, informed by desktop reviews, site surveys and liaison with University of Plymouth.
4) Existing meter data analysis and carbon footprint assessment.
5) Benchmarking existing carbon footprint against recognised industry standards/targets.
6) Identification of any recommended future additional metering and sub-metering opportunities.
7) Outline assessment for potential building envelope decarbonisation intervention measures
8) Technical assessment of potential decarbonisation interventions for each building.
9) Assessment and presentation of calculated impact to energy and carbon footprint of each identified potential decarbonisation intervention.
10) Identification of an any potential electrical supply capacity upgrade requirements.
11) Cost analysis of each identified potential decarbonisation intervention.
12) Identification of key risks associated with identified potential decarbonisation interventions.

4. Buildings and Description of Existing

4.1 Portfolio

The main campus has over 70 buildings, which range in size and complexity from domestic houses repurposed as offices, through to large iconic multi-storey buildings for education and research. These buildings range in age from current day construction to 100+ years old, and represent an eclectic mix of building uses.

Over the last 2-5 years, the University have undertaken a series of studies and assessments to review the building stock with a view to identifying means of decarbonising their buildings and reducing energy consumption. These previous studies have helped to identify the key buildings that are considered to have the greatest potential to benefit from improvement measures, and therefore included within this plan. These buildings are listed below, and indicated in Figure 6;

- Davy
- Smeaton
- Link
- Scott Building
- The House
- Marine Building

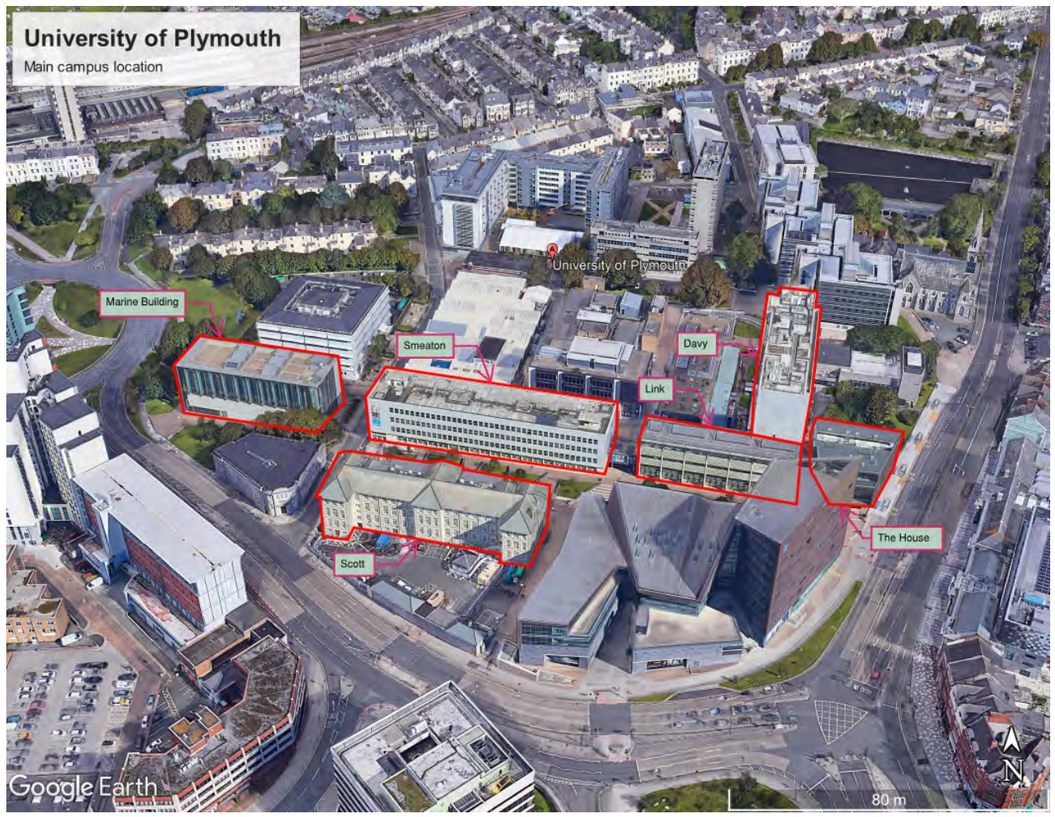


Figure 6 - Aerial view identifying buildings in scope

As can be seen, all of the above listed buildings are in close proximity to each other, and form the hub of the campus, which sits in the middle of Plymouth.

The above buildings constitute approximately 30% of GIA of all buildings on the campus, hence offer a great opportunity to make a significant reduction in carbon due to their prominent size and associated energy usage.

Of particular note is the fact that five of the buildings are already connected via a district heating scheme, fed from gas fired boilers and CHP unit within Davy building.

In addition, Scott building is particularly old, and is served from its own gas fired boiler plant.

All of the above therefore present great opportunities to make some meaningful savings through decarbonisation of their heating/cooling systems, hence included in this study.

For reference, it is noted that University of Plymouth are owner occupiers of all of the above buildings, hence they present a viable portfolio against which to make some significant improvements.

4.1.1 Planned Preventative Maintenance

Planned Preventative Maintenance (PPM) activities are almost exclusively undertaken by external contractors, on behalf of the University.

The university operate a comprehensive asset management software called 'Zetasafe', for which all assets are barcoded, and registered on the compliance / maintenance management software. This allows planned maintenance schedules to be produced, for associated works to be undertaken in a planned fashion.

As a result of this system, the maintenance regimes for the MEP services within the buildings in question were of a good standard, and have resulted in extending the economic life of many of the systems due to regular maintenance regimes being in place.

4.2 Davy Building

4.2.1 Description

Davy building is located within the heart of the University of Plymouth campus in the centre of Plymouth. Davy building was handed over in 1967, and currently has a gross internal area of approx. 10,510m^2.

Hours of occupancy are typically 0800 – 1800, although 24 hour access is permitted for research staff.



Figure 7 – The Davy Building location

The building is currently used for science and research purposes, comprising predominantly research laboratories and cleanrooms with some offices, teaching and breakout spaces. The building contains a number of home office approved laboratories. The building use by floor is summarised in Table 2 below. The building adjoins the Link building (included within the scope of this plan) and also the main hall (excluded from the scope of this plan).

Table 2 - Davy building usage by floor

Level	Primary Usage
00 & basement	Plant / electrical rooms, home office aquarium laboratories
01	Laboratories (including CL1, CL2, CL3, home office / restricted access), clean rooms
02	Laboratories (including CL1, CL2, Controlled temperature rooms, home office / restricted access)
03	Laboratories (including CL1, CL2, home office / restricted access), autoclaves
04	Cellular office spaces, open study bays, laboratories (including CL1, CL2, CL3, home office / restricted access)
05	Laboratories (including CL1, CL2), teaching spaces, cellular offices
06	Laboratories (including CL1, CL2, home office / restricted access, temperature controlled, wet), cellular offices, open plan
07	Open plan study areas, teaching spaces, cellular offices, laboratories (including CL1, CL2)
08	Laboratories (including CL1, CL2, cool rooms, home office / restricted access), mechanical plant rooms associated with home office laboratories

4.2.2 Existing building fabric overview

Exact details of the building fabric are unknown.

The original build was a brickwork construction and due to the year of construction the building fabric is likely to include minimal thermal insulation.

The building was overclad in 1999 in a major project to improve the thermal performance by application of insulated rain screen cladding and upgrading of windows to double glazed units. Note that the stair cores within the building were provided with single glazed units only.

The over cladding manufacturer has advised that the cladding and windows have the below thermal performance

- Wall cladding – 0.28 W/m^2 k (100mm rockwool insulation + air gap)
- Double glazed windows – 1.6 W/m^2 k

The building fabric appears in fair condition, commensurate with the age of the building. Double glazed window units appeared to be in good working order with seals in reasonable condition for their age.

It was reported by the building users that the single glazed units within the stair cores were in very poor condition and were often seized in the open position.

4.2.3 Incoming Utilities Overview

4.2.3.1 Incoming electrical supply

The campus is served via a 11kV HV ring distribution network which is owned and operated by the UoP. The agreed capacity for the site is 3985 kVA and the site peak demand between 2019 and 2021 is 2278kVA. As a result, the available site spare capacity is 1707kVA.

The main Western Power Distribution (WPD) connection and metering is via the Davy building substation.

Davy building is served by 2no. 800kVA transformer which supply the main switchboard within the Davy building LV switchroom. It is noted that one of the transformers has been disconnected to facilitate the connection of the CHP unit, hence is redundant but could be used in the future. This was not visibly inspected due to access restrictions, so should be verified.

The LV switchboard serves the Davy building and the Link building LV distribution system.

The main switchboard appears to have adequate supplies to accommodate additional loads, without major infrastructure upgrades.

4.2.3.2 Incoming gas supply

The incoming gas supply enters from Drake Circus into the gas intake room in the basement.

The main gas meter is located at entry to the building, from where the gas serves the below areas

- Metered supply serving laboratories and sub metered supply to student union
- Metered supply to level 08 laboratories serving Bunsen burners
- Metered supply to AHU
- Unmetered Supply to 3rd floor food labs in Link building
- Unmetered supply to boiler room to serve
    - 2no boilers, unmetered
    - 1no CHP, sub metered

4.2.4 Existing MEP Systems Overview

4.2.4.1 Davy district heat network

The Davy building houses the gas plant serving the district heat network, comprising

- 1no CHP (527kW$_{th}$)
- 2no LTHW boilers (585kW each)

The district heat network serves the below via a 1171kW plate heat exchanger within Davy plantroom

- Davy building – south
- Davy building - north
- Smeaton building
- Link building
- Brunel building

The district heat network serves the below via remote plate heat exchangers

- Babbage building – 438kW heat exchanger
- Marine building – 519kW heat exchanger
- The House – 200kW heat exchanger

The CHP engine is an EnerG 500 unit and was installed in 2012. The CHP has the following performance details, although is understood to have been recently de-rated in terms of its available output.

- Electrical output – 450kWe (505kWe)
- Total heat output – 527kWth
- Gas input (gross) – 1436kW

The district heat network operates at the set points

- Flow temperature from CHP = 90°C
- Temperature at top of, and from, fully charged thermal store = 90°C
- Temperature at bottom of fully charged thermal store = 85°C
- Flow temperature from heating boilers = 90°C
- Flow temperature required by plate heat exchanger (PHE) = 85°C
- Flow temperature to primary system following mixing with return water = 86°C
  (This allows 1°C for pipe losses between temperature sensor and PHE)
- Maximum return temperature to CHP = 80°C

It was advised that the CHP suffers reliability issues and as such is often non-operational due to availability of replacement components. When operating, the CHP is electrically led with thermal dumping of heat.

Record drawings indicated the district heat network was installed circa 2012, concurrent with the installation of the CHP. The existing boiler plant within Davy was incorporated within the district heat network plant and so are likely to be significantly older than the rest of the network, although their exact age is currently not established. It is unlikely that the boilers serving the district heat network are nearing or beyond the end of their serviceable life expectancy.

The pump sets serving Davy building, Link Building and Smeaton and Brunel buildings were not replaced during the CHP installation project and so are anticipated to have been installed before 2012, although their exact age is currently not established.

4.2.4.2 Heating System Overview

Davy building is heated from the district heat network outlined in section 4.2.4.1 via a flow and return LTHW system.

The LTHW system generally serves perimeter heating, which appear to be rudimentary finned convectors with very poor room controls. Some more recently refurbished areas such as the cellular offices are heated by LTHW radiators with thermostatic radiator valves.

It is assumed that the central pipework system and the perimeter heating systems are of the same age as the building, so circa 60 years of age. The pipework and emitters appear to be in fair condition commensurate with the age of the system however CIBSE guide M advises a serviceable life for heating pipework and emitters of 40 years. Therefore the main heating distribution within Davy building is considered beyond expected economic life.

Further intrusive investigations will be required to assess the condition of the existing heating system. Pipework insulation was observed to be in poor condition or missing in a number of instances, however full survey of pipework systems was not undertaken so extent of missing or poor condition insulation unknown.

4.2.4.3 Domestic Hot Water

Domestic hot water within Davy building is generally via electric point of use water heaters. Water heaters are either dedicated to a single sanitaryware fitting or serve multiple sanitaryware fittings. There is no centralised domestic hot water system serving Davy building. The domestic hot water requirements within the building are primarily wash hand basins, laboratory sinks and cleaner sinks.

4.2.4.4 Cooling system overview

A large proportion of the laboratory spaces are provided with comfort cooling. Where provided comfort cooling is via DX split cooling system (electrically driven refrigerant circuit).

Cooling systems are controlled locally by standalone occupant controllers without BMS timeclock control. It appears no controls exist to prevent space heating and comfort cooling working against each other.

4.2.4.5 Ventilation system overview

The majority of the occupied spaces within Davy building are provided with mechanical ventilation.

The ventilation systems reflect the ad-hoc nature of the refurbishment of the building, comprising local dedicated MVHR units located within the ceiling void of the spaces served. Intake and exhaust ductwork is routed to louvres locally within the façade.

The mechanical ventilation systems all featured local occupant controllers offering speed control only, no time clock control was observed.

There is no centralised ventilation system serving the Davy building.

Cellular offices with external windows are predominantly naturally ventilated.

4.2.4.6 LV Distribution

Power is routed from the main switch panel in the basement and rises through the building via two risers in the North and South of the building.

The risers contain distribution boards that crudely serve each half of the building.

Power is then distributed through each floor within the ceiling void of the central corridor.

4.2.4.7 Lighting

The building comprises a mixture of LED and fluorescent tube lighting. LED lighting is generally provided in areas where more recent refurbishment projects have been undertaken.

Lighting controls are generally manual switching with PIR absence detection. No daylight dimming or perimeter lighting controls was observed during the surveys.

The condition of the lighting installation varies throughout Davy building, reflecting the ad-hoc nature of the refurbishment projects undertaken within the building.

4.2.4.8 Sub-metering

Davy building is fitted with the below sub metering.

Heat meters

- Davy North
- Davy South

Electric meters

- Davy – CHP Incomer
- Davy – South Main Meter
- Davy – North Incomer
- Davy – 291 Rm310
- Davy – AC panel
- Davy – BMS DB Room
- Davy – Boiler Control Panel
- Davy – Boiler Room DB
- Davy – DB2 Floor 8
- Davy – MCCB Essential Supplies – Aquarium
- Davy – MCCB Essential Supplies – Basement Comms room
- Davy – MCCB Essential Supplies – Floor 8 Restricted
- Davy – New LHT Busbar
- Davy – New PWR Busbar
- Davy – 3rd flr N Elec Meter EMCP3 1
- Davy – 3rd flr N Elec Meter EMCP3 2
- Davy – 3rd flr N Elec Meter EMCP3 3
- Davy – 3rd flr N Elec Meter EMCP3 4
- Davy – 3rd flr N Elec Meter EMCP3 5
- Davy – 3rd flr N Elec Meter EMEP3 1
- Davy – 3rd flr N Elec Meter EMUPS 1

C3ntinel energy monitoring software provides the below reporting groups

- Total Small Power & lighting – less PCs - Davy
- Total HVAC – Davy
- Total IT - Davy

4.2.5 Existing low or zero carbon technologies

It is understood there are currently no low or zero carbon technologies serving Davy building.

4.2.6 Existing or planned heat networks

Davy building houses the gas fired plant that serves the district heat network as summarised in section 4.2.4.1

The University aspire to implement a future 5GDH network on the campus site, potentially utilising ground source heat pumps within the footprint of Brunel workshops. The development for NEDF building is being future proofed for compatibility with this future 5GDH network.

Decarbonisation plans for each building should include future proofing for compatibility with the 5GDH network. This would comprise providing ground floor plant area to house internal water to water heat pumps which would connect to the 5GDH network.

4.2.7 Implemented decarbonisation interventions

It is understood that no major decarbonisation interventions have been completed within Davy building.

4.2.8 Future plans for the building

The building has undergone various modifications and refurbishment projects during its life. The building was originally used for teaching spaces however the primary use has gradually been changed to science and research laboratories through a number of projects over an extended period. These projects have typically been undertaken on an ad-hoc basis and not as a whole building approach.

The university are currently developing a ‘science strategy’, in which Davy building’s function is being considered as a whole, with a view to consolidating and rationalising it’s use to make it more effective. The outline intentions at this time are to seek to bring departments and uses together, relocate different laboratories to better suit related adjacencies, and potentially move some of the office accommodation into more suitable accommodation. In short, these potential future plans would likely take place in 3-5 years’ time, and are still in their infancy, awaiting review and approval. Anecdotally, the anticipated usage of the building is unlikely to significantly change from its current usage, although there is the likelihood that the density of laboratories and specialist controlled temperature rooms would increase (adding a greater thermal load to the building).

4.3 Link Building

4.3.1 Description

Link Building is a four-storey building within the main University of Plymouth campus in the centre of the city. Link is situated between, and linked to, the Davy and Smeaton building. Link houses teaching spaces, offices and laboratories for dietetics and psychology studies.

The building is estimated to have been constructed in the 1950s, and has a gross internal area of approximately 2384m^2.

Hours of occupancy are typically 8am–6pm, but 24hr access is permitted.



Figure 8 – The Link Building location

Link building includes a mixture of workspaces including laboratories, break-out spaces, and small consultation rooms. The Link building shares access and adjoins the Davy building on each floor. A link-bridge connects to Smeaton on the first floor. Link building shares a stair core with the Davy building. Apart from this there is a stair at the west side of the building between the second and third floors.

Table 3 - Link building usage by floor

Level	Primary Usage
00	Laboratory spaces, including cooking workshop.
01	Teaching spaces, computer suites, offices, consultation rooms, breakout space
02	Offices, consultation rooms
03	Open-plan office space/function/event space

4.3.2 Existing building fabric overview

Based on photographs of the original construction, the original build was a brickwork construction and due to the year of construction the building fabric is likely to include minimal thermal insulation.

It is unknown when the building improvements were undertaken, but it can be seen from photographs that there have been extensive enhancements to the thermal performance of the building. This includes recladding to improve thermal performance, replacement of windows to feature double glazing, and external solar shading.

The thermal performance of the building is thought to be good following the enhancements.

4.3.3 Incoming Utilities Overview

4.3.3.1 Incoming electrical supply

The Link building LV supply is directly fed from the Davy building LV switchboard and HV substation to local dilapidated MCCB boards. The MCCB boards feed the mechanical equipment and distribution boards supplying the final circuitry on each floor via a busbar system.

The MCCB boards appear to have been fully utilised with no spare capacity for significant loads.

4.3.3.2 Incoming gas supply

There is a local gas supply that serves the range cooker in the ground floor dietetics lab, and several gas outlets in the other ground floor labs. This supply is a sub-mains system fed from the Davy building.

Since the heating system is from the university district heat network, there is no gas supply associated with heating plant.

4.3.4 Existing MEP Systems Overview

4.3.4.1 Heating System Overview

Link building is heated from the district heat network outlined in section 4.2.4.1 via a flow and return LTHW system. Since the Davy building is connected to Link the pipework connections are directly from the Davy building.

The majority of the spaces are heated using perimeter heating, namely radiators. In a number of areas, trench heaters or finned tube radiators are installed. Perimeter heating is controlled via TRVs on each heat emitter. Some smaller internal private study rooms are provided without heating.

Due to the recent refurbishment of this system the system and components are in good condition.

In two rooms on the third floor there were permanent electric panel heaters. These feature local temperature and time controls.

4.3.4.2 Domestic Hot Water

All hot water outlets are served by local instantaneous electric, hot water heaters. Hot water outlets are at sinks and washbasins. There is no central hot water system.

4.3.4.3 Cooling system overview

There is no cooling to the building. Where there are high heat loads such as server racks, these are cooled using fresh air only.

4.3.4.4 Ventilation system overview

Most spaces are naturally ventilated by way of openable windows. Where there are internal rooms, these have mechanical ventilation. In the absence of central air handling plant these are assumed to be fed from local fan units within the ceiling voids.

4.3.4.5 LV Distribution
Power is routed from the main switch panel in the Link building and rises up through the building via two dedicated electrical risers on the east and west wings of the building.

The risers contain metered distribution boards at each level, that crudely serve each half of the floor plate.

4.3.4.6 Lighting
Aside from two rooms that featured LED, the lighting throughout was via fluorescent light fittings.

4.3.4.7 Sub-metering
There is no submetering that is visible on the C3ntinel monitoring platform.

Heat meters
The Link building has one main heat meter that records the heat supplied from the Davy CHP.

Electric meters
The Link building has one main electric meter. On the Energy Monitoring Software, this meter is indicated as being 'archived', but it is clear there are current trends and logs being recorded. This has been reported, and will be rectified.

C3ntinel energy monitoring software provides the below reporting groups

- Electric – Total Small Power and Lighting – less PC's
- Electric – Total IT

4.3.4.8 Existing low or zero carbon technologies
There are no current low or zero carbon technologies associated with the Link building.

4.3.5 Existing or planned heat networks
Link building currently derives its heat from the district heat network as summarised in section 4.2.4

Since the Link building derives heat from the Davy CHP unit, any future modifications to this heat source will affect the Link building. Finding an alternative low-carbon heat source that can provide the required high-grade heat will provide immediate reduction in associated CO2 emissions without compromising on performance or requiring a change to building heat emitters.

4.3.6 Implemented decarbonisation interventions
N/A

4.3.7 Future plans for the building
There are no significant plans to fundamentally change the building in the foreseeable future. However, there is a business case relating to the dietetics use, which may result in some minor reorganisation in the building, but is not considered likely that this will materially affect the building's load profiles, and therefore the impact of the outcomes of this heat decarbonisation plan.

4.4 Smeaton

4.4.1 Description
Smeaton is a four-storey building within the main University of Plymouth campus in the centre of the city. Smeaton is connected to "Link" building at its eastern end by a link bridge on the first floor.

The building is estimated to have been constructed in the 1950s, and has a gross internal area of approximately 5233m².

Hours of occupancy are typically 8am–6pm, but 24hr access is permitted.



Figure 9 - The Smeaton Building location

The activities undertaken in Smeaton are admin offices, engineering computer suites and small-scale fabrication workshops.

Table 4 - Smeaton building usage by floor

Level	Primary Usage
00	Plant, Admin offices, Mechanical fabrication workshops
01	Computer suites, office space
02	Computer suites, small lecture theatre/teaching space
03	Teaching space, electrical testing workshops, computing

4.4.2 Existing building fabric overview

Exact details of the building fabric are unknown.

The original build was a brickwork construction and due to the year of construction the building fabric is likely to include minimal thermal insulation.

The building was overclad in 1999 along with Davy Building in a major project to improve the thermal performance by application of insulated rain screen cladding and upgrading of windows to double glazed units. Note that the stair cores within the building were provided with single glazed units only.

The over cladding contractor has advised that the cladding and windows have the below thermal performance:

- Wall cladding – 0.28 W/m² K (100mm rockwool insulation + air gap)
- Double glazed windows – 1.6 W/m² K

The building fabric appears in fair condition, commensurate with the age of the building. Double glazed window units appeared to be in good working order with seals in reasonable condition for their age.

4.4.3 Incoming Utilities Overview

4.4.3.1 Incoming electrical supply

The Smeaton electrical supply is via a switched fuse LV switchboard located within the ground floor plantroom.

The LV switchboard is fed from the 1000kVA Scott building substation with an alternative supply from the Davy building south LV switchboard. The Smeaton incoming supply and alternative supply is limited to 400A.

4.4.3.2 Incoming gas supply

Since the heat is derived from the university district heating network there is no gas supply to the building.

4.4.4 Existing MEP Systems Overview

4.4.4.1 Heating System Overview

Smeaton building is heated from the district heat network outlined in section 4.2.4.1 via a flow and return LTHW system.

The majority of spaces are heated via radiators located around the perimeter of each room. These were controllable using the local radiator TRVs.

In some of the ground floor workshop areas, these spaces are heated by are radiant panels mounted or through the ventilation systems. The ventilation systems have local room controllers.

Due to the recent refurbishment of this system, the wet heating system and components are in good condition.

4.4.4.2 Domestic Hot Water

The domestic hot water outlets throughout the building are an even split between local electric water heaters and sourced from a central system. The hot water outlets are primarily for wash hand basins.

4.4.4.3 Cooling system overview

There is DX cooling only to server/IT rooms with high heat loads. External condenser units are located at roof and at ground floor level.

4.4.4.4 Ventilation system overview

The majority of spaces show evidence of mechanical ventilation. In the absence of central air handling plant, these are assumed to be via local fan-coil units within the ceiling void. The control of these systems is via room controllers.

On the ground floor workshops there were several fume cupboards with associated local extract ventilation systems.

4.4.4.5 LV Distribution

Power is routed from the main switch panel in the ground floor plant room, and rises up through the building via two dedicated electrical risers on the east and west wings of the building.

The risers contain metered distribution boards at each level, that crudely serve each half of the floor plate.

4.4.4.6 Lighting

Following a recent overhaul of the light fixtures in Smeaton, most light fittings were installed with LEDs. Some Compact Fluorescent Lights (CFL) were installed in circulation spaces and stair cores.

4.4.4.7 Sub-metering

Smeaton Building is fitted with the below sub metering.

Heat meters

N/A

Electric meters

- Gnd Floor Busbar
- 1st Floor Busbar
- 2nd Floor Busbar
- 3rd Floor Busbar
- Roof Plant Room
- DB03 Elec

C3ntinel energy monitoring software provides the below reporting groups

4.4.5 Existing low or zero carbon technologies

Solar thermal panels are installed on the roof. The roof panels contribute heat to the main hot water cylinder. This system is reported to be no longer functional, and is understood to be due to be stripped out in the near future.

4.4.6 Existing or planned heat networks

There are no significant plans to change the building in the foreseeable future.

4.4.7 Implemented decarbonisation interventions

N/A

4.4.8 Future plans for the building

Smeaton currently houses a water cooled High Performance Computer (HPC) system. There are plans to relocate this to Portland Square in the foreseeable future. Therefore we would envisage a reduction in electrical load of approximately 30kW (data taken from metering information associated with IT loads).

4.5 Scott Building

4.5.1 Description

The Scott building is a three-storey building within the main University of Plymouth campus in the centre of the city. It is of the oldest buildings on campus at approximately 100 years old, and has a gross internal area of approximately 3652m².

Hours of Occupancy are typically 8am–6pm,



Figure 10 - The Scott Building location

The building houses workshops used for the production of art, including specific processes such as letter presses, photo development, and ceramics. On the upper floor there are some music and film studio spaces for recording and editing.

Table 5 - Scott building usage by floor

Level	Primary Usage
Basement	Mechanical and Electrical Plant rooms
00	Art workshops, kiln room, Lecture theatre
01	Lecture theatre, photo development, offices, film processing
01M	Staff offices on mezzanine level
02	Studio Spaces, equipment store, and recording/editing suites

4.5.2 Existing building fabric overview

The current fabric is as per the original building. This building is constructed from thick stone and has a high thermal mass. The external finish of the building is as per its original construction; however, subsequent modifications include a largely glazed façade on the building's north face. The age of the building would suggest high potential for fabric improvements. However, due to the historic nature of the building, its prominent nature, and its construction, there are limited opportunities to improve the building's performance

The Scott building features single glazed sash windows. On the south face of the building secondary glazing has been installed to improve the thermal performance.

4.5.3 Incoming Utilities Overview

4.5.3.1 Incoming electrical supply

The Scott building is supplied from the Scott building 1MVA HV substation. This substation serves the Scott building switchboards, Smeaton Building, and an alternative supply to the Davy building.

The incoming device rating is unknown; however, the switchboard would require upgrading to accommodate the new supplies for the ASHPs. The existing switchboard utilises switched fuses of up to 200A.

4.5.3.2 Incoming gas supply

The incoming gas supply is in a boiler plant room at basement level.

4.5.4 Existing MEP Systems Overview

4.5.4.1 Heating System Overview

The Scott building features 2no. 261kW gas fired boilers within the basement level plantroom running at 80/60°C flow and return temperatures.

The majority of rooms are heated via perimeter radiators, controlled by local TRVs, however the lecture theatres, equipment store, and north facing studios are heated via an air handling unit.

The heating system was installed in 2007 and the condition of this system seems fair, however there were reports by some building Occupiers that since the purpose of some rooms have changed since this installation the heating strategy is no longer suitable for these spaces.

4.5.4.2 Domestic Hot Water

All outlets surveyed were electric local water heaters. These were mostly wash hand basins, but some sinks were located within the workshops as a wash down facility.

4.5.4.3 Cooling system overview

There is DX cooling only to server/IT rooms with high heat loads. External condenser units are located at roof and at ground floor level.

4.5.4.4 Ventilation system overview

There was extensive mechanical ventilation installed in the Scott building assumed to have been installed during the 2007 renovations. These ventilation units were installed in the corridor space and served the larger workshops and teaching spaces.

A separate large AHU in the roof level plantroom served the two lecture theatres and equipment store. Within the lecture theatres these were ducted to low level to provide displacement ventilation to the spaces.

4.5.4.5 LV Distribution

Power is routed from the main switch panel in the basement and rises through the building via two dedicated electrical risers on the east and west wings of the building.

The risers contain metered distribution boards at each level, that crudely serve each half of the floor plate

4.5.4.6 Lighting

4.5.4.7 Sub-metering
Scott building is fitted with the below sub metering.

Heat meters
N/A

Electric meters
- Boiler Room Elec
- DB – LP1W Elec
- DB8 Elec
- East Wing BusBar Elec
- LP2E Elec
- LP2W Elec
- LP3
- MCCB Board Elec
- Plumbers WS Elec
- East Wing BusBar Elec

C3ntinel energy monitoring software provides the below reporting groups

- Total Small Power and Lighting – Less PC's
- Total HVAC
- Total IT

4.5.5 Existing low or zero carbon technologies
There are no current low or zero carbon technologies associated with the Scott building.

4.5.6 Existing or planned heat networks
Scott building sits apart from the main university district heating system as it has its own heat generating plant.
There are no plans at present for the Scott building to be adopted into a future heat network.

4.5.7 Implemented decarbonisation interventions
N/A

4.5.8 Future plans for the building
There are no significant plans to change the building in the foreseeable future.

4.6 Marine Building

4.6.1 Description

The marine building sits on the south-western edge of the campus, as indicated in Figure 11. The building was constructed, and handed over in 2012, making it one of the newer buildings on the campus.

The marine building is a purpose designed research facility, containing a series of specialist tanks and flumes to study a range of oceanography, as well as a series of lecture rooms, simulators, offices, and support spaces. Generally speaking, the building operates as an office-type environment, with access to a few specialist areas for practical research and training.



Figure 11 - Marine Building location

Marine Building comprises of six principal floors, including a mezzanine around the ocean and coastal tanks, and a basement plantroom. The approximate gross internal area of the building is 4,014m^2.

The building is typically occupied from 0600 – 1800, with occasional access out-of-hours and over the weekends, dependant on any research activities being undertaken.

Table 6 - Marine Building usage by floor

Level	Primary Usage
Basement	Plantroom / Incoming electrical services / pumps supporting wave tank
00	Tank Hall
Mezzanine	Workshops, Tank Hall
01	Teaching spaces, simulators
02	Offices
03	Offices

4.6.2 Existing building fabric overview

The building is a concrete framed construction, with concrete slabs, offering large open-plan spaces within the building.

The façade is a mixture of high-performance curtain walling, insulated panels, and glazing.

Due to the age of the building, the condition of the fabric is excellent, and is known to be of a high thermal performance.

4.6.3 Incoming Utilities Overview

4.6.3.1 Incoming electrical supply

A dedicated incoming 1500kVA electrical supply enters the basement level on the western side of the building.

From the HV transformer, an LV supply enters the adjacent switchroom, from where all subsequent power distribution emanates.

The switchboards are in good condition with adequate spare capacity for additional supplies for the Marine building's ASHPs without the need to upgrade the existing switchgear and incoming submain cables.

4.6.3.2 Incoming gas supply

The building is not served with any natural gas.

4.6.3.3 Incoming district heating

A low temperature hot water supply enters the basement plantroom, from the district heating mains fed by Davy Building, see below.

4.6.4 Existing MEP Systems Overview

4.6.4.1 Heating System Overview

Primary heating is derived from the University District Heating System, which feed into the district heating mains. District heating pipework is buried below ground, and enters the basement plantroom at high level, before connecting onto a plate heat exchanger. The approximate flow temperature of the district heating coming into the building is 70°C.

Secondary pump sets then distribute LTHW to a low loss header, from where a series of further pumped circuits distribute heat around the building.

Heating of the Marine Building is almost exclusively through radiators and trench heating, with all heat emitters being provided with local temperature control (TRV's and thermostats as applicable).

The floor plates and rooms are well split down with regards to zonal controls, with controls provided at each floor level, plus additionally to individual or small groups of rooms. These controls are all monitored and controlled via the BMS and Energy Metering System.

The main entrance was provided with a vertical air curtain, which was presumed to be electrically heated (connection details could not be ascertained from the non-intrusive survey).

4.6.4.2 Domestic Hot Water

The building obtains its primary heating for hot water via roof mounted solar panels, which feed into a calorifier in the basement plantroom. The secondary heat source is then derived from the district heating LTHW supplies. There is an existing electric immersion heater also installed within the calorifier.

Hot water flow and return pipework is distributed around the building within dedicated risers, and fed out to the wash hand basins and cleaner sinks located at both ends of the building, within the cores.

4.6.4.3 Cooling system overview
There are no mechanical cooling provisions within the building.

It is noted that the building contains exposed concrete soffits and general structure throughout, and exploits a night time cooling strategy with the ventilation strategy.

4.6.4.4 Ventilation system overview
All offices, circulation spaces, and teaching spaces are naturally ventilated through openable windows.

There are a number of double height stacks within the building, that have opening rooflights to promote good air flow, and offer night time cooling capabilities via the BMS.

The Tank Hall is provided with a dedicated air handling unit, that is located externally. This is used to control the room conditions to sit at 1°C above the water temperature. The air handling plant is provided with LTHW for tempering of the air only (i.e. no cooling provisions included).

Toilets, kitchenettes, and cleaner cupboards are provided with local extract ventilation.

The Server Room is provided with local supply and extract fans to manage heat gains from the room.

4.6.4.5 LV Distribution
Power is routed from the main switch panel in the basement, and rises up through the building via two dedicated electrical risers on the east and west wings of the building.

The risers contain metered distribution boards at each level, that crudely serve each half of the floor plate.

Power is distributed within the raised access floors on the office and teaching floor plates, and is run exposed within containment in the Tank Hall area.

4.6.4.6 Lighting
The lighting within the Marine Building is LED throughout, and provided with Occupancy controls (absence detection), and daylight dimming. The building has been designed to maximise daylighting also, with high glazing areas and north facing rooflights, that bring lighting into the building.

4.6.4.7 Sub-metering
Due to the age of the building, the metering in the building is very good, and provides a clear means of identifying energy usage throughout the building. The sub metering is identified below.

Heat meters
Heat meters are installed on the following circuits;

- Primary circuit (on incoming LTHW from district heating)
- Constant Temperature circuit
- Variable Temperature circuit
- Hot Water system

Electric meters
The extent of electrical metering is very good, with all small power and lighting being metered.

In addition, the high power consuming areas of the building (simulator room, tank room, server room etc.) are all provided with their own distribution boards that are separately metered.

In total, there are 52 electrical meters in the building, that report to the C3ntinel system.

4.6.4.8 Existing low or zero carbon technologies
The building generally relies on good passive measures to reduce its energy consumption, to reduce its carbon footprint.

However, in addition, there is a small solar thermal panel that provides the primary form of heating to the domestic hot water system.

4.6.4.9 Existing or planned heat networks
As described in 4.6.4.1, the Marine Building is already connected to the district heating network that is fed from Davy Building.

Since the Marine Building derives heat from the Davy CHP unit and boilers, any future modifications to this heat source will affect the Marine building. Finding an alternative low-carbon heat source that can provide the required high-grade heat will provide immediate reduction in associated CO_2 emissions of the Marine Building without compromising on performance or requiring a change to building heat emitters.

4.6.4.10 Implemented decarbonisation interventions
Due to the age of the building, and the fact it was designed to achieve an ‘Excellent’ BREEAM rating, there has not been as great a potential to implement any decarbonisation measures to date.

We understood that the building has undergone a BMS optimisation in the past, along with the other buildings on the campus.

4.6.5 Future plans for the building
There are no significant plans to change the building in the foreseeable future.

The only minor modifications that were discussed with an academic related to some internal modifications to create some modular control rooms, although this is unlikely to affect any of the servicing strategies or loads.

4.7 The House

4.7.1 Description

The House is a metal clad three-storey building within the main University of Plymouth campus in the centre of the city. Having been completed in 2013 the House is one of the most recent developments on campus.

The House is used for performing arts and features a large theatre area for hosting stage productions that may be open to the public. Hours of Occupancy are typically 8am–6pm, but if there are performances in the evening the maximum Occupancy will be outside of these hours.



Figure 12 - The House Building location

The House includes a large theatre auditorium, several studio spaces and office spaces. The House has a gross internal area of approximately 1709m^2.

Table 7 - The House building usage by floor

Level	Primary Usage
00	Main stage, technicians' workshop, hospitality
01	Performance Studio, circulation
02	Rehearsal studio, Data, and equipment store
03	Offices, Plantroom, roof space

4.7.2 Existing building fabric overview

The House has good fabric performance due to its relatively recent completion. Additionally, it is thought that the U-value rating of external walls goes well beyond the building regs requirement for that period as evidenced by its "A" rated EPC.

4.7.3 Incoming Utilities Overview

4.7.3.1 Incoming electrical supply

The incoming supply is fed from the Davy building LV switchboard to the House MCCB board located in the ground floor riser. The MCCB board appears to be limited by a 630A electronic trip unit set at 500A and serves the LV distribution system throughout the building. An additional separate backup supply is fed from the Davy building LV switchboard.

The MCCB board appears to have limited spare electrical capacity and spare ways for additional loads.

4.7.3.2 Incoming gas supply

Since the heat is derived from the university district heating network there is no gas supply to the building.

4.7.4 Existing MEP Systems Overview

4.7.4.1 Heating System Overview

The heat to the House is derived from the university district heating network, which is provided via a plate heat exchanger in the third-floor plant room. Space heating is achieved via underfloor heating. The main theatre is heated via an air handling unit supplying warm air to the underside of the bleachers as per a displacement ventilation system. The controls for this system is via a controller mounted within the room.

There is one office space on the third floor that is heated via fresh air through an electric heater battery. This room was intended as a lab space that has now been converted to an office.

4.7.4.2 Domestic Hot Water

Domestic Hot water is generated centrally from the LTHW heat source via a calorifier in the third-floor plant room and then distributed throughout the building to the outlets. The hot water outlets are mostly wash hand basins but also some showers on the ground floor.

4.7.4.3 Cooling system overview

There is no cooling to the building. Where there are high heat loads such as server racks, these are cooled using fresh air only.

4.7.4.4 Ventilation system overview

In the ground floor changing rooms Mechanical Ventilation with Heat Recovery (MVHR) provide tempered air efficiently while in the wet rooms and WCs the air is extracted without heat recovery.

The main auditorium has a natural ventilation system with low, mid, and high-level vents that exploit the stack effect to passively ventilate the space. Additionally, there is a mechanical ventilation system that provides displacement ventilation to the theatre. This is served from an AHU located on the roof. The control for this system is via a controller mounted within the room.

The performance studio on the first floor also, has a natural ventilation system with low, and high-level vents that passively ventilate the space. Additionally, there is a mechanical ventilation system that provides low-level supply and high-level extract to the studio. This is served from an AHU located on the roof. The control for this system is via a controller mounted within the room.

4.7.4.5 LV Distribution
Power is routed from the main switch panel on the ground floor and rises through the building via a dedicated electrical riser on the west wing of the building.

The riser contains metered distribution boards at each level, that serve the floor plate.

4.7.4.6 Lighting
The lighting throughout is LEDs controlled via PIR sensors in most spaces.

4.7.4.7 Sub-metering
The House building is fitted with the below sub metering. However, it has been reported that there are some inconsistencies with the meter readings recorded.

Heat meters
- Meters logging the LTHW usage of the heating manifold on each floor.
- Meters logging the LTHW usage of the AHUs
- Meter logging the LTHW usage of the Hot water calorifier

Electric meters
- Meters to each distribution board throughout the building
- Display screen equipment
- Equipment rack
- Vertical transport
- Rehearsal room
- Entrance and Social Foyers
- Rainwater harvesting
- MCCP

4.7.4.8 Existing low or zero carbon technologies
- Rainwater harvesting
- Passive stack ventilation

4.7.4.9 Existing or planned heat networks
Link building currently derives its heat from the district heat network as summarised in section 4.2.4

4.7.4.10 Implemented decarbonisation interventions
N/A

4.7.5 Future plans for the building
There are no significant plans to change the building in the foreseeable future.

5. Energy Consumption and Carbon Emissions

5.1 Summary

All energy billing information is available for the University and coupled with the energy management system (C3ntinel), there is a very good level of detail available against which analysis have been made, as are discussed under each of the buildings in this section of the report.

The C3ntinel system provides an interactive platform within which energy metering can be interrogated down to a minute, and trends, alarms and other useful reporting can be generated.

Data is available from approximately January 2015; hence trend logs and an accurate baseline can be provided for the buildings.

The University, being owner Occupiers pay for the energy bills of each of the buildings.

Generally speaking, the metering configurations have provided a sufficient level of information against which to make some informed decisions on potential decarbonisation measures. That said, there would be greater benefit in adding as many sub-meters as possible to monitor different systems more closely in the buildings. For example, separate heat metering to individual air handling plant would be useful, as too would heat metering to floors or smaller zones within the buildings.

A degree of analysis has had to be undertaken to break out some of the heat loadings for the buildings, to split out domestic hot water generation, either from the central low temperature hot water (LTHW) supplies, or as an assessment on the electrical loads.

5.2 Davy

5.2.1 Utility meter data analysis

Half hourly meter readings have been provided for Davy for the period 01/01/2017 to 31/12/2017 as this is effectively the last complete annual data set collected under normal operation (i.e., before the building's usage was affected by the impact of lockdown due to the COVID-19 pandemic). Unfortunately, there is incomplete data for more recent years, so it is assumed that the consumption during 2017 is typical of the building. The annual energy use for 2018 was compiled; however there appears to be rather low electricity usage in March compared to the other months. No heating was recorded for the months of June, July, August, and September 2018; however, it is assumed that no heating was used during these warmer months.

Electricity consumption was taken from the main electricity meter, and heat consumption was taken from the north and south heat meter, to ascertain a total annual heat consumption from the district heating system.

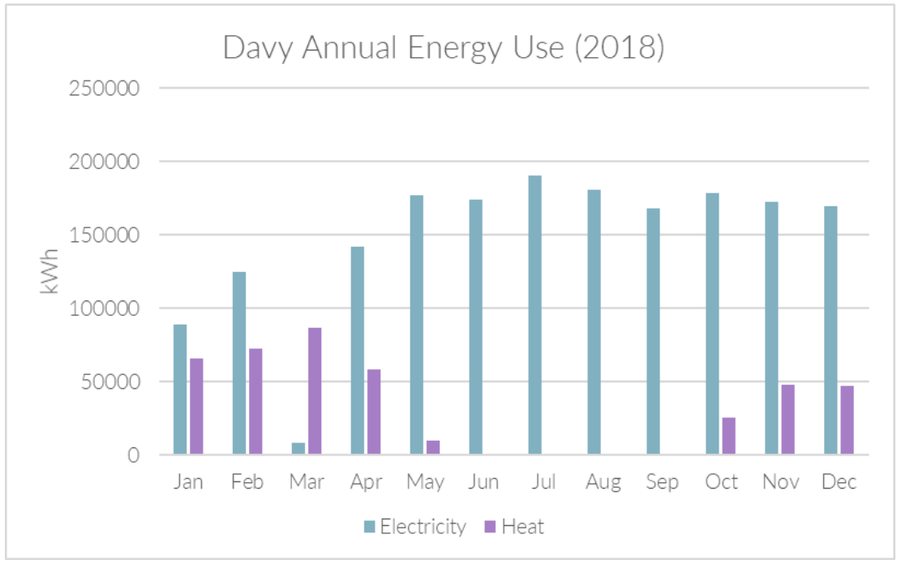


Figure 13 - Davy Annual Energy Usage (2018)

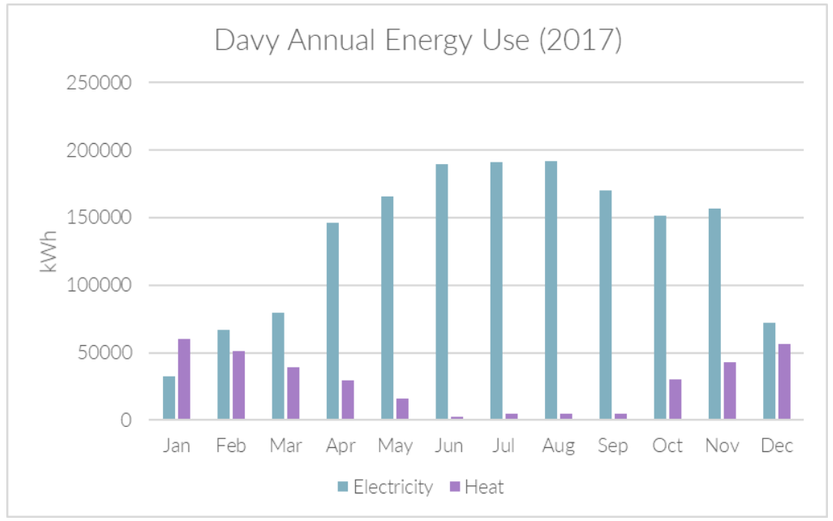


Figure 14 - Davy Annual Energy Usage (2017)

Electricity usage increases with warmer months, and peaks during mid-summer, potentially implying that the majority of the electricity usage was due to the demand for the electrically driven DX split cooling systems, to cool the laboratory spaces. The heating trend closely follows the seasonal external temperatures, where higher demand is associated with colder winter months.

It was seen that a significant majority of monthly heating consumption was from the north side heat meter, as displayed in the graph below.

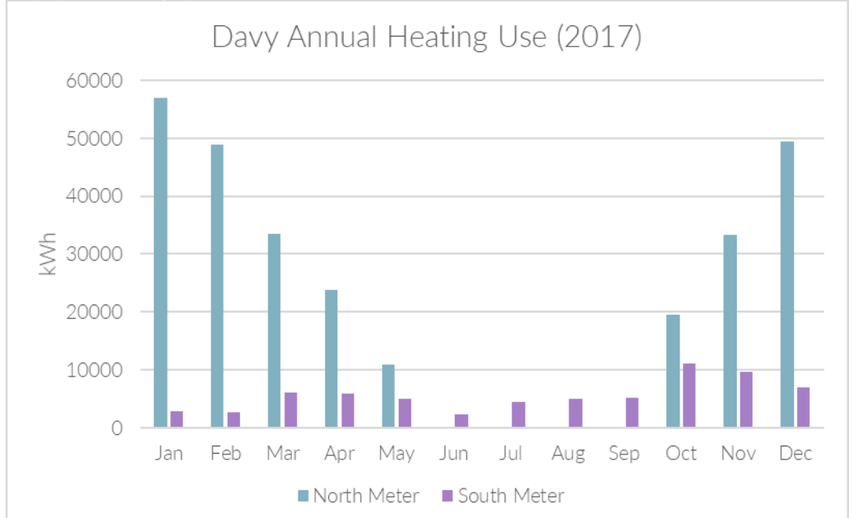


Figure 15 - Davy Annual Heating Use (2017)

The effectiveness of the heating system can be further checked by plotting the mean daily gas consumption against the mean daily Degree Days for each month. The clustering of the resultant points close to a linear trend line is evidence that heating demand is closely matched to the external ambient temperature, which can be seen to be the case for Davy in the graph below.

The intersection of the trend line with the vertical axis at the origin suggests that there are minimal standing losses. The correlation coefficient of the two data sets *r*, as indicated on the graph, was calculated to be 0.974. As this value is close to 1, this further suggests that there is a close relationship between degree days and gas consumption of Davy.

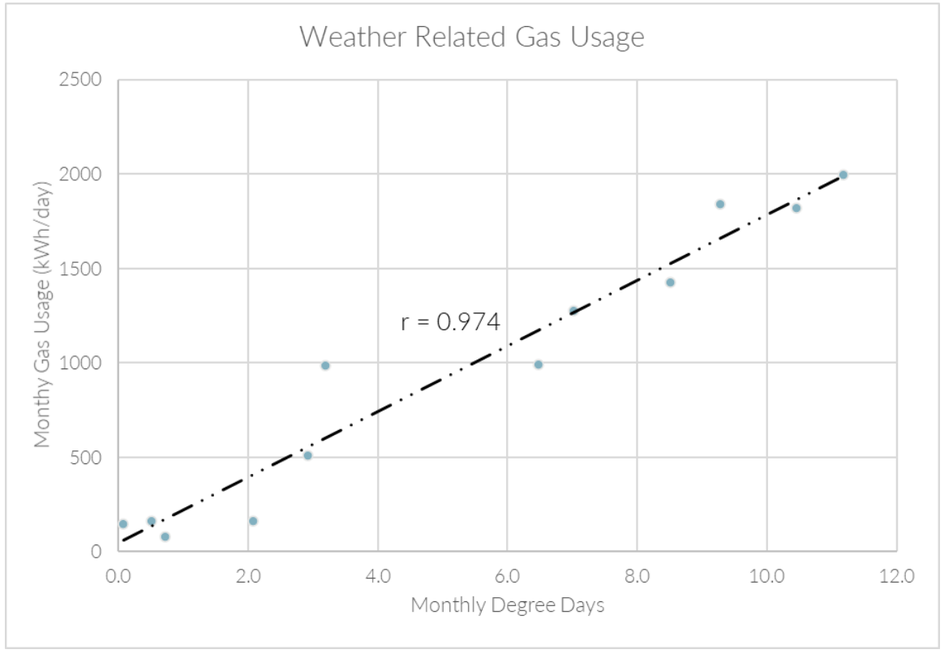


Figure 16 - Davy Weather Related Gas Usage

5.2.2 Existing carbon footprint benchmarking

The carbon footprint of Davy was compared to energy consumption benchmarks for existing science laboratory education spaces, taken from CIBSE Guide F.

Table 8 - Davy Building Carbon Footprint Benchmarking

Energy	Actual (2017)		Benchmark (CIBSE Guide F)	
	kWh/m^2	$kgCO2/m^2$	kWh/m^2	$kgCO2/m^2$
Electricity	159.61	23.30	175.00	25.55
Heat	34.00	6.24	132.00	24.22
Total		29.54		49.77

The annual heat usage compares favourably to the benchmark values, with the usage being 26% of the value, suggesting that Davy is being heated in an efficient manner. However, there is potential scope for reducing electricity consumption, as the usage is 91% that of the target value. Higher consumption of electricity was expected in Davy, compared with newer buildings on campus.

The carbon factors utilised in the above and all subsequent assessments are the BEIS greenhouse gas reporting conversion factors, with an average taken from 2022 to 2036.

5.3 Link

5.3.1 Utility meter data analysis

Half hourly meter readings have been provided for Link for the period 01/01/2017 to 31/12/2017 as this is effectively the last complete annual data set collected under normal operation (i.e., before the building's usage was affected by the impact of lockdown due to the COVID-19 pandemic).

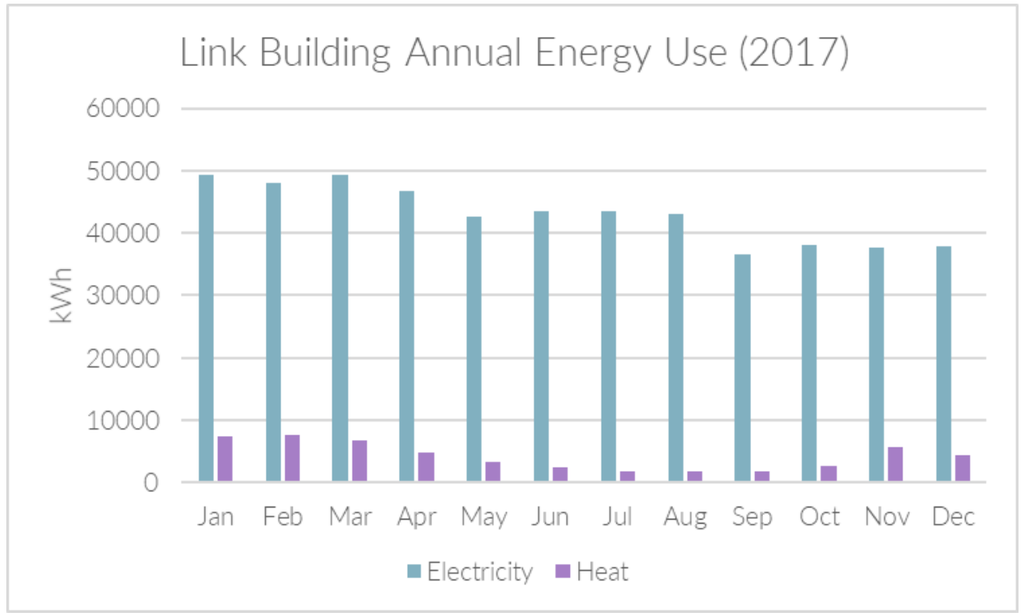


Figure 17 - Link Building Annual Energy Usage

Electricity consumption appears to remain relatively constant throughout the year, however, remain high during the summer months. The heating consumption trend appears to follow that of seasonal external temperatures, with the winter months resulting in the highest usage. The electricity consumption per month is much higher than the heating consumption.

The effectiveness of the heating system was further checked by plotting the mean daily gas consumption against the mean daily Degree Days for each month. The wider scatter plot of mean daily gas consumption suggests that the heating systems are not being closely controlled to external weather conditions.

The correlation coefficient *r*, as indicated on the graph, was calculated to be 0.868, suggesting that the relationship between the heating usage and external temperatures are not as closely linked as Davy.

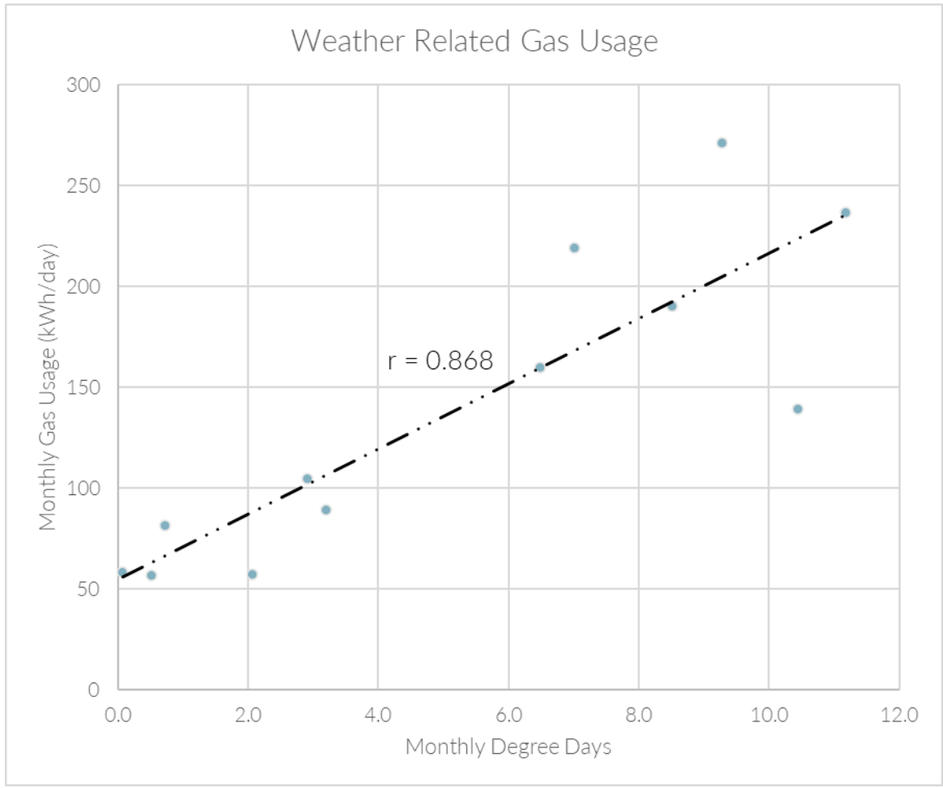


Figure 18 - Link Building Weather Related Gas Usage

5.3.2 Existing carbon footprint benchmarking

The carbon footprint of Link was compared to energy consumption benchmarks for university campus buildings, taken from CIBSE TM46.

Table 9 - Link Building Carbon Footprint Benchmarking

Energy	Actual (2017)		Benchmark (CIBSE TM46)	
	kWh/m^2	kgCO2/m^2	kWh/m^2	kgCO2/m^2
Electricity	216.55	31.62	80.00	11.68
Heat	21.11	3.87	240.00	44.04
Total		35.49		55.72

The annual electricity consumption per m^2 is high when compared to the industry benchmark, at 270% of the target value, suggesting significant opportunity to reduce the electricity usage and the concurrent environmental and economic effects. It was expected that electricity usage would be higher in Link, compared

with the newer buildings on campus. Much like Smeaton, we have noted that the annual heating demand per m^2 is much lower than the industry benchmark. Whilst it is possible that there may be some error in the gathered meter data, particularly when data is interpolated, the low heating load could be attributed to high internal heat gains, negating the need for high consumption of heating.

Despite this, it recommended that sub-metering per floor, and of plant equipment, of both heat and electricity consumption be made available in Link, to further understand and investigate the usage. This amount of sub-metering would be beneficial as it will allow greater and more accurate energy-saving recommendations to be made.

5.4 Smeaton

5.4.1 Utility meter data analysis

Half hourly meter readings have been provided for Smeaton for the period 01/01/2018 to 31/12/2018 as this is effectively the last complete annual data set collected under normal operation (i.e., before the building's usage was affected by the impact of lockdown due to the COVID-19 pandemic).

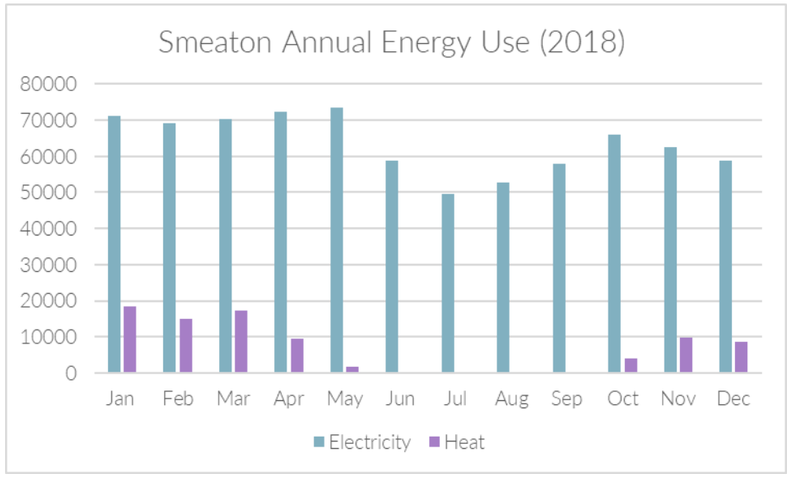


Figure 19- Smeaton Annual Energy Usage

Electricity consumptions appears to be at its highest during the University term-time months and dropping during the summer break. Heating consumption appears to follow that of seasonal external temperatures, and whilst there was no data recorded for the months of June, July, August, and September, we have attributed no heating demand during these months to the external summer temperatures and the University summer break.

The heating demand can be seen to peak during colder months, and the effectiveness of the heating system was further checked by plotting the mean daily gas consumption against the mean daily Degree Days for each month. The correlation coefficient r was calculated to be 0.958 suggesting that in general, the heating system in Smeaton is closely controlled to external weather conditions.

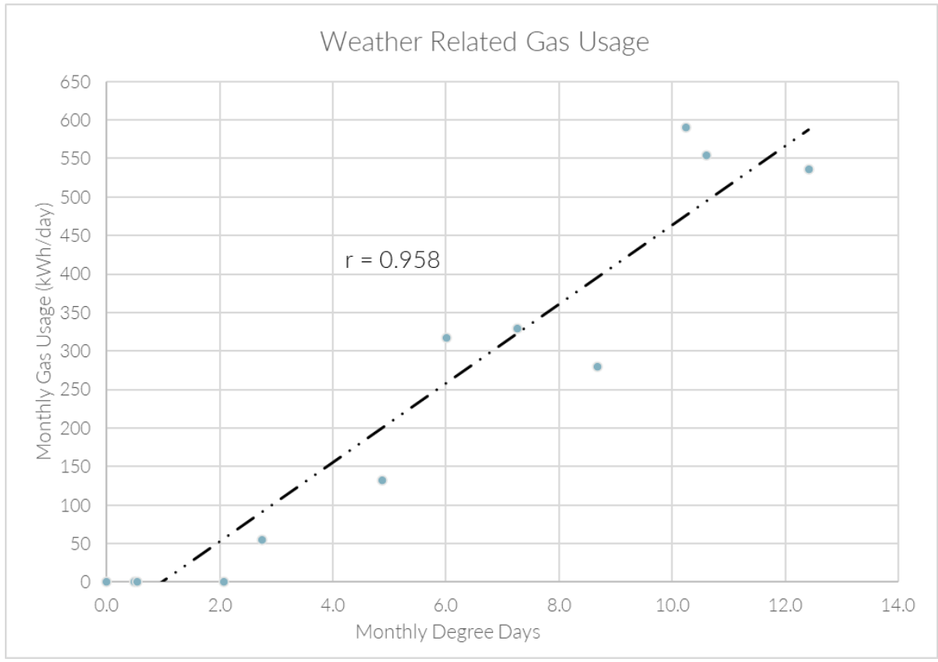


Figure 20 - Smeaton Building Weather Related Gas Usage

5.4.2 Existing carbon footprint benchmarking

The carbon footprint of Smeaton was compared to energy consumption benchmarks for university campus buildings, taken from CIBSE TM46.

Table 10 - Smeaton Building Carbon Footprint Benchmarking

Energy	Actual (2018)		Benchmark (CIBSE TM46)	
	kWh/m^2	kgCO2/m^2	kWh/m^2	kgCO2/m^2
Electricity	145.76	21.28	80.00	11.68
Heat	16.11	2.96	240.00	44.04
Total		24.24		55.72

The annual electricity consumption per m^2 fairs higher than the industry benchmark value, at 182% that of the target, suggesting significant opportunity to reduce the electricity usage and the concurrent environmental and economic effects. High electricity usage for Smeaton was expected compared to the newer buildings on campus.

We have noted that the total annual heating demand per m^2 for Smeaton is much lower than the industry benchmark, at 6.7% of the target. We have associated this to the resultant heat load of the IT equipment within the computer rooms instigating a lower overall heating demand during university term time. As such, it can be determined that the heating demand of Smeaton attributes little to the overall district heating network.

5.5 Scott

5.5.1 Utility meter data analysis

Half hourly meter readings have been provided for Scott building for the period 01/01/2017 to 31/12/2017 as this is effectively the last complete annual data set collected under normal operation (i.e., before the building's usage was affected by the impact of lockdown due to the COVID-19 pandemic). Scott receives heating from an individual gas supply.

Gas meter readings are incomplete for the months of June, July, August, and September; however, we have attributed this to the external summer temperatures and the University summer break causing no demand for heating. Unfortunately, records throughout 2019 were incomplete and we have assumed that the 2018 period was an atypical example of energy use, due to the cold wave that occurred between Feb-March 2018 throughout the British Isles. It is however positive that accurate, expected data was obtained for 2017, and is a typical example of annual energy usage under normal, pre COVID-19 conditions.

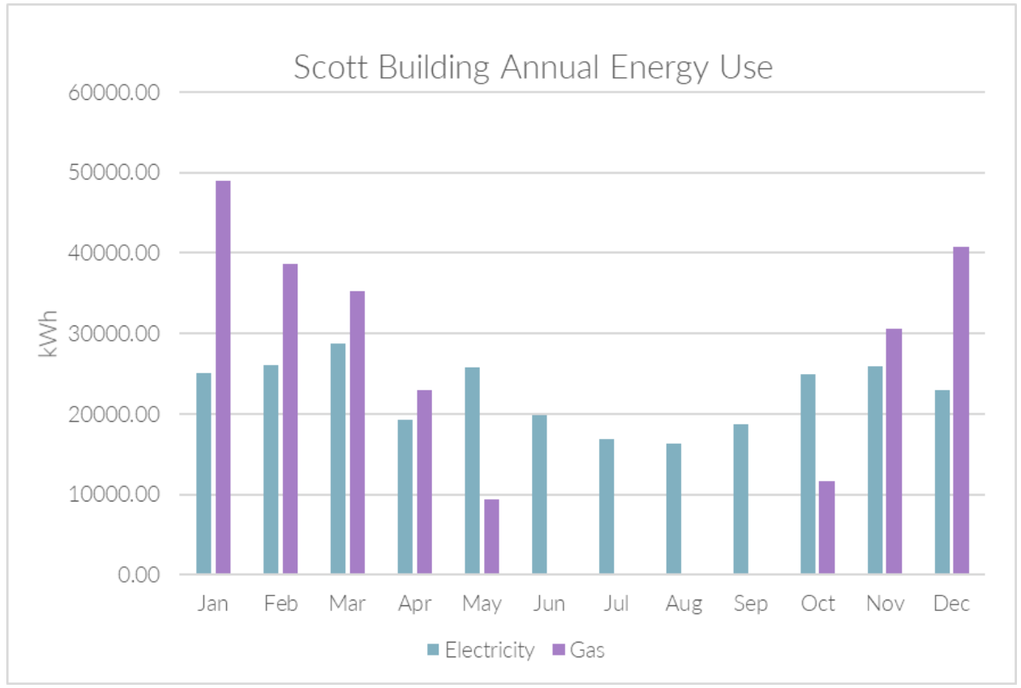


Figure 21 - Scott Building Annual Energy Usage

Electricity consumption appears relatively consistent throughout the year, which would suggest that any reduction in artificial lighting demand during the longer daylight hours of the summer months is being offset by increased demand for mechanical ventilation and cooling to counter the higher ambient temperatures.

The profile of the monthly gas usage appears to closely follow that of the seasonal external temperature, with winter months resulting in the highest usage.

The effectiveness of the heating and control systems can be further checked by plotting the mean daily gas consumption against the mean daily Degree Days for each month. The clustering of the resultant points close to a linear trend line is evidence that heating demand is closely matched to the external ambient temperature, so the controls systems in Scott would appear to be working well, which can be seen to be the case for the in the graph below.

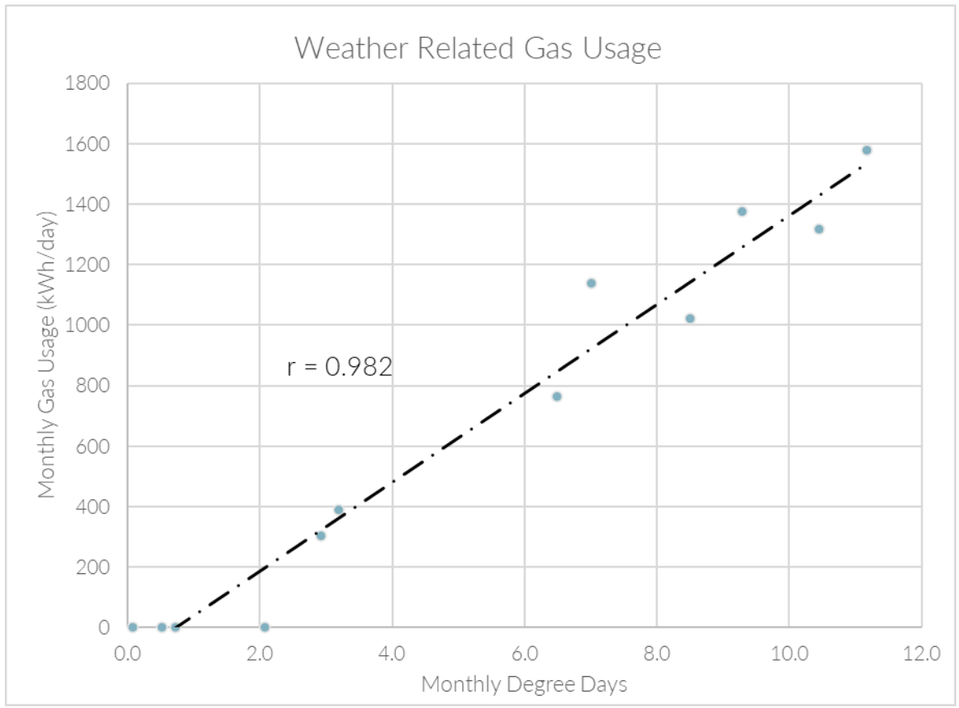


Figure 22 - Scott Building Weather Related Gas Usage

The correlation coefficient *r* was calculated to be 0.982. As this value is close to 1, this further suggests that there is a close relationship between degree days and gas consumption of The House.

5.5.2 Existing carbon footprint benchmarking

The carbon footprint of Scott was compared to energy consumption benchmarks for university campus buildings, taken from CIBSE TM46.

Table 11 - Scott Building Carbon Footprint Benchmarking

Energy	Actual (2017)		Benchmark (CIBSE TM46)	
	kWh/m²	kgCO2/m²	kWh/m²	kgCO2/m²
Electricity	74.01	16.34	80.00	18.70
Heat	65.24	14.77	240.00	50.65
Total		31.11		69.35

The gas usage per m² compares favourably to a benchmark reference valve, with usage of 7% that of the target value. Electricity usage, however, is higher, at 93% of the target value.

This suggests that Scott is operating in a relativity energy efficiency manner in terms of heating, however, there is opportunity for significant savings in terms of electricity usage and associated economic and environmental costs.

5.6 Marine Building

5.6.1 Utility meter data analysis

Electricity metering for the Marine Building appears to be accurate, and data is available from 2015 to the present. Half hourly meter readings have been taken for the period 01/01/2019 to 31/12/2019 as this is effectively the last complete annual data set collected under normal operation (i.e., before the building's usage was affected by the impact of lockdown due to the COVID-19 pandemic).

Heat metering for the Marine Building was taken from C3ntinel by summing up the monthly data recorded by each individual submeter. There is some incomplete data recorded on C3ntinel for the years of 2018 and 2019, and so the year 2017 was used to gauge a more accurate representation of building heat usage before the COVID-19 pandemic.

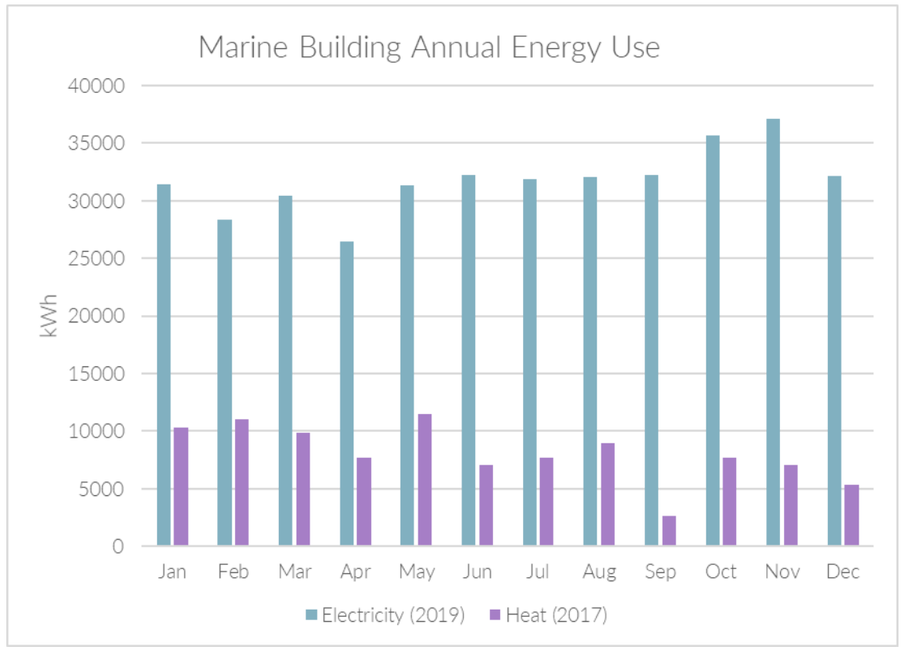


Figure 23 - Marine Building Annual Energy Usage

The monthly electrical usage remains relatively constant throughout the year, the high consumption during winter can be attributed to increase demand for lighting. Electrical usage per plant equipment was not available, as such it is recommended to meter all plant equipment to accurately determine the consumption, which would aid the optimisation of the systems.

The effectiveness of the heating system in the Marine Building was determined by plotting the mean daily heat consumption against the mean daily Degree Days per month.

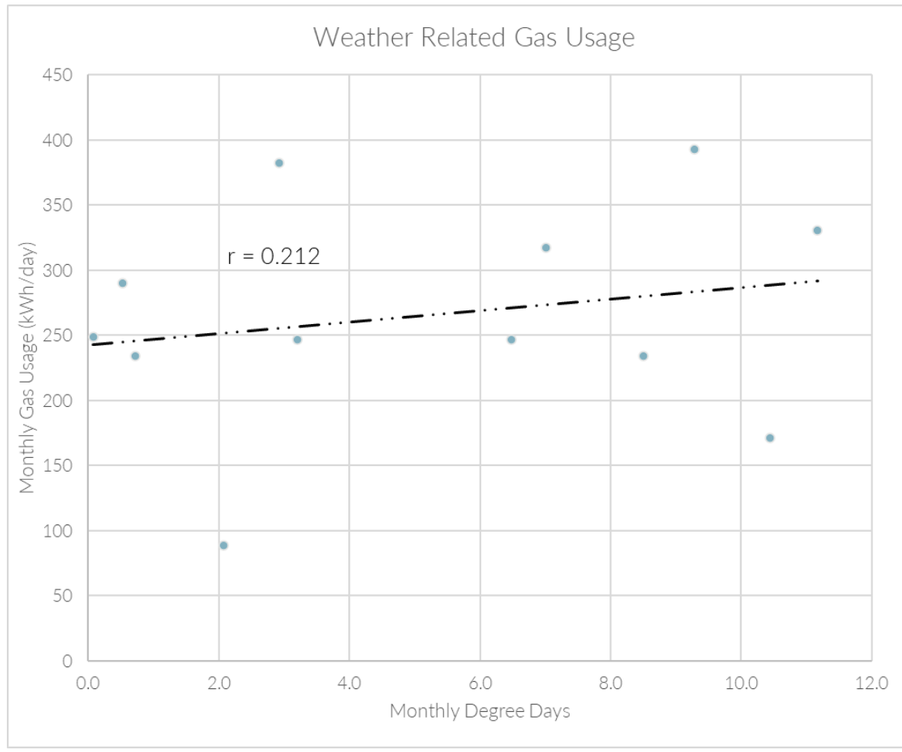


Figure 24 - Marine Building Weather Related Gas Usage

The wider scatter plot depicted on the graph indicates that the heating is not closely matched to the external ambient temperature; suggesting there is scope for the improvement of the controls system in the Marine Building. The correlation coefficient *r* was calculated to be 0.212, further reinforcing this. The Marine Building may benefit from further submetering and investigation into the accuracy of the current recorded data.

5.6.2 Existing carbon footprint benchmarking

The carbon footprint of the Marine Building was compared to electricity consumption benchmarks for university campus buildings.

Table 12 - Marine Building Carbon Footprint Benchmarking

Energy	Actual (2019)		Benchmark (CIBSE TM46)	
	kWh/m^2	kgCO2/m^2	kWh/m^2	kgCO2/m^2
Electricity	91.52	13.26	80.00	11.68
Heat	23.19	4.26	240.00	44.04
Total		17.62		55.72

The annual electricity usage per m^2 is higher than the benchmark for university campus buildings, at 114% that of the target value, suggesting that there is scope for potential electricity consumption reduction and the associated economic and environmental savings.

5.7 The House

5.7.1 Utility meter data analysis

Half hourly meter readings for The House are available and generally resemble accurate consumption, however it was noted that there were sudden, instantaneous spikes of extremely high electricity usage at certain points in the day. The cause of this is unknown, and it is recommended that the sub-meters are inspected for faults. However, Hoare Lea examined the readings on C3ntinel to exclude the spikes of high usage, in order to ascertain a more accurate annual electricity usage. Data was taken from the year of 2019.

Nevertheless, it is useful that sub-metering for heat usage is available for The House, displaying the usage for the various underfloor heating zones, the hot water system, and the office. There is also sub-metering of the individual AHUs, however there is no data available for AHU1.

Half-hourly heat meter readings are available from the Plate Heat Exchanger meter, with the underfloor heating (UFH), hot water and office space meter data assumed to sum up to the former, which is on the incoming side of the system. However, it has appeared that the various zone sub meters do not sum up to the data gathered from the Plate Heat Exchanger meter.

Upon some examination of C3ntinel, data gathered from the sub-meters seemed inaccurate; with the exception of the ground floor UFH zone; which appears to contain accurate and expected consumption data, which is a positive. Data was taken during the year 2017, which followed expected monthly usage and was the last complete annual data set collected under normal operation (i.e., before the building's usage was affected by the impact of lockdown due to the COVID-19 pandemic).

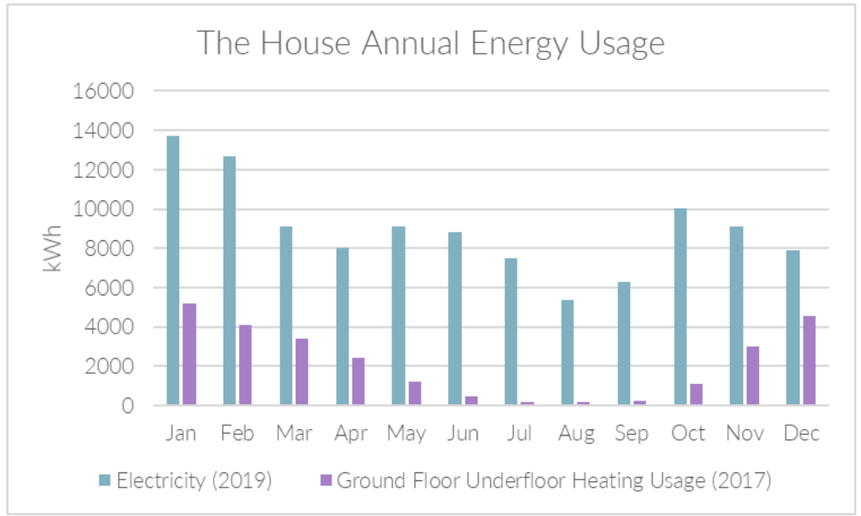


Figure 25 - The House Annual Ground Floor Underfloor Heating Usage

The ground floor UFH zone heating usage appears to closely resemble that of seasonal external temperature, with usage increasing during the winter months.

The effectiveness of the ground floor UFH zone heating system can be further checked by plotting the mean daily gas consumption against the mean daily Degree Days for each month. The clustering of the resultant points close to a linear trend line is evidence that heating demand is closely matched to the external ambient

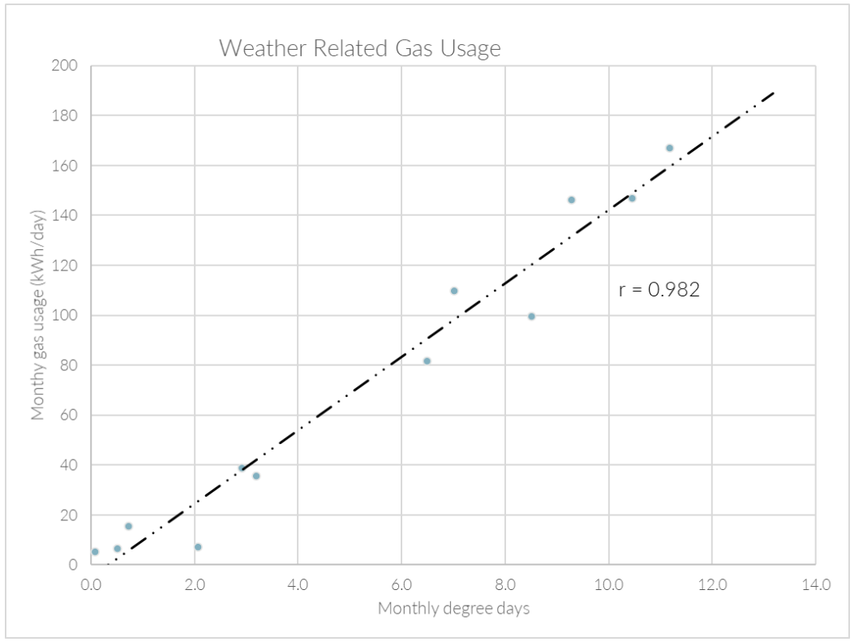


Figure 26 - The House Weather Related Gas Usage

The correlation coefficient *r* was calculated to be 0.982. As this value is close to 1, this further suggests that there is a close relationship between degree days and gas consumption of The House.

5.7.2 Existing carbon footprint benchmarking

The ground floor UFH zone energy annual usage was used to compare against energy consumption benchmarks, for existing theatre buildings taken from CIBSE Guide F. As The House is considered a new building, good practice benchmarks have been taken, as it is assumed the building is more energy efficient, compared to the older university buildings.

The energy consumption per m^2 has been calculated by using the total annual consumption of the ground floor UFH usage, and the estimated internal area of the ground floor.

Table 13 - The House Carbon Footprint Benchmarking

Energy	Actual		Benchmark (CIBSE Guide F)	
	kWh/m^2	kgCO2/m^2	kWh/m^2	kgCO2/m^2
Electricity	62.97	9.19	180.00	77.07
Heat	37.78	7.59	420.00	84.42
Total		16.13		103.35

Whilst the carbon footprint of the heat usage calculation is not a true representation of the carbon footprint of the whole building, and only captures the ground floor UFH zone, it is evident that the heating system in The House is energy efficient, as the ground floor UFH zone usage per m^2 being only 9% that of the benchmark value for an energy efficient theatre.

The annual electricity usage compares favourably to that of the benchmark, at 34% of the target value. This suggests that The House is operating in an energy efficient manner.

5.8 Recommendations

Following the above review of the energy metering, there are a number of recommendations made to the University of Plymouth to help improve the management and reporting of energy, and subsequent carbon emissions, as summarised below. They are categorised by building for ease of understanding. As an approximate cost estimate, £1,500/meter installation is a basis for budgeting, for which overall costs are indicated in section 11 of this report.

5.8.1 Davy Building

- Heat sub-metering of individual floors and primary zones of the building (32 No.)
- Electrical metering of the AHU (1 No.)
- Electrical metering of DX split cooling systems (1 No. per unit).
- Electrical metering of dedicated water heaters (~ 30 No.).

5.8.2 Link Building

- Electrical metering of the hot water heaters (~ 10 No.).
- Electrical metering of local fan coil units (1 No per FCU, ~15 No. total).
- Sub-metering of individual rooms of the building (4 No. electric, 4 No. heat).
- Investigate the accuracy of heat consumption metering data.

5.8.3 Smeaton

- Heat metering of individual floors of the building (4 No.).
- Investigate low heat consumption metering data, however, we have ascertained that low heat consumption is attributed to large internal heat gains from IT equipment.
- Electrical metering of the hot water heaters (~9 No).
- Electrical metering of DX cooling systems (1 No. per unit).
- Electrical metering of local fan coil units (1 No. per FCU, ~28 No. total).

5.8.4 Scott Building

- Investigate missing/incomplete metering data.
- Sub-metering of individual floors of the building (4 No. gas, 4 No. electric).
- Electrical metering of the hot water heaters (~9 No.).
- Electrical metering of DX cooling systems (1 No. per unit).
- Heat and electrical metering of the AHU (1 No. heat, 1 No. electric).

5.8.5 Marine Building

- Resolve heat metering anomalies, and ensure all meters are accurately recording data via BMS / Energy Management System.
- Further metering of the solar heating system (6 No.).
- Heat and electrical metering of AHU (1 No. heat, 1 No. electric).

5.8.6 The House

- Investigate the reasoning behind the large spikes of electricity usage.
- Resolve some missing meter readings on the sub-meters.
- Electrical metering of the AHU (1 No.)

6. Summary of Decarbonisation Intervention Opportunities

6.1 Overview

Based on the review of the record documentation provided, site visits, and dialogue with the University, the following potential decarbonisation intervention opportunities have been identified for the various buildings.

6.2 Davy Building

6.2.1 Initial intervention measures

The following interventions are recommended to consider carrying out in the short term in order to inform the more detailed stages of a decarbonisation roadmap:

- Installation of further heat meters to all sub-circuits, including floor-by-floor, to air handling plant, and to areas of high energy consumption.
- Installation of electric meters to all point of use water heaters, to better monitor hot water usage and identify opportunities for further reductions.
- An LTHW water quality laboratory test of the condition of the circulating fluid, including chemical composition and presence of suspended solids/corrosion
- non-destructive testing of the existing pipework to assess its thickness in case of corrosion
- installation of a corrosion monitoring system
- commissioning of a thermographic survey of the building fabric's thermal performance to ascertain any specific areas on which to make a focus.

6.2.2 Building fabric decarbonisation opportunities

The following potential fabric improvement interventions have been identified for exploration at the Davy building:

- Installation of new and/or additional roof insulation. In order to assess the impact that this measure would have, the current roof insulation provision will need to be established. Current plant located on the roof, and the roofing to all the upper floor laboratories would need to be removed to have new insulation applied.
- Installation of double glazing on the remaining single glazed windows (noting that double glazing has already been fitted in most of the Occupied rooms). Single glazing appears to only remain in some of the circulation cores.
- Sealing of existing windows where they are draughty and have not already been sealed.

It is recommended to consider commissioning a thermographic survey to identify in detail the areas where meaningful improvements could be made to the thermal performance of the building envelope, and engaging an architect to develop design proposals to implement such improvements.

6.2.3 Ventilation systems decarbonisation opportunities

Due to the nature of the Davy Building, there are a plethora of ventilation systems serving the building, of which many are very aged and unlikely to be of a particularly high efficiency. There is a potential to generate some reasonable carbon savings through the replacement of old fans/AHUs with modern fans/AHUs with high efficiency impellors, motors, and variable speed drives.

Further (significant) savings would be achievable by overhauling the ventilation distribution, and implementing a demand controlled ventilation system to all areas served, such that ventilation rates could be ramped down through the use of variable air volume controllers, based upon room air quality and/or Occupancy.

Equally, there are numerous fume extract systems which are high energy consuming items of plant. These are generally legacy plant and ductwork systems that are modified and reused over time, and are unlikely to be operating at their best potential. There is opportunity to yield energy savings and subsequent carbon emissions through the following steps;

- Replace old fans with new, high efficiency fans.
- Consider a variable air volume extract provision, linked to operation of fume cupboards
- Ensure correct operation of fume cupboards (lower sashes when not in use)
- Seek to group banks of fume cupboards onto fewer fans.

Subject to a more holistic overhaul of the building, there would be opportunity to fully redesign the ventilation systems to meet the current or future requirements. The systems have been adapted, modified, and added to over the years, with many compromises having to be made to work within the constraints. If the opportunity arose with a full refurbishment of the building, then new, high efficiency ventilation plant with heat recovery and free cooling capabilities could be provided, which could yield significant energy reductions, and therefore carbon savings. This would be very disruptive though, so would need to be carefully considered.

6.2.4 Heating & cooling systems decarbonisation opportunities

The following potential opportunities were identified to decarbonise the heating system:

- Installation of motorised control valves to heat emitters, room air temperature sensors and zoned controls to allow each room to be individually temperature controlled with its own adjustable timeclock and temperature set back.
- Integration of heat pump technologies, as below options
    - Integration of low temperature air source heat pumps into the secondary circuit returns to the boiler system, to pre-heat when the circuit temperatures are sufficiently reduced via weather compensation. Note this option will not fully decarbonise the heating system as gas fired boiler plant will still be required to meet peak loads however a significant proportion of the heat pumps will be sized to cater for a significant portion of the heating demand.
    - Integration of high temperature air source heat pumps into the secondary circuit returns to the boiler system, to pre-heat when the outdoor air temperature is mild enough to allow a high temperature air source heat pump to operate at a sufficiently high coefficient of performance (COP) to reduce carbon emissions in comparison to gas boilers. Note this option will not fully decarbonise the heating system as gas fired boiler plant will still be required to meet peak loads however a significant proportion of the heat pumps will be sized to cater for a significant portion of the heating demand.
    - Integration of low temperature air source heat pumps into the secondary circuit returns to the boiler system, to heat as much as possible, with boiler top-up, alongside replacement of all heat emitters to operate at low temperatures. Note this option will not fully decarbonise the heating system as gas fired boiler plant will still be required to meet peak loads however a significant proportion of the heat pumps will be sized to cater for a significant portion of the heating demand.
    - Wholesale replacement of gas fired heat generating plant with electric driven heat pump technologies. This option would require wholesale replacement of the entire heating system including heating pipework and emitters to ensure compatibility with heat pump flow temperatures, should low temperature heat pumps be selected. As such the disruption arising from the implementation of this option will be significant and therefore this option becomes particularly attractive if the whole building is considered for refurbishment. However, if minimal intervention is deemed the more appropriate solution, then high temperature heat pumps could be installed to replace the gas fired plant, by providing flow temperatures at the same condition as the gas fired solutions. There would be a reduction in operating efficiencies of high temperature vs. low temperature heat pumps, but they would still attract a very good carbon reduction when compared to gas fired solutions.
    - Installation of reversible or simultaneous heating and cooling heat pump technologies to cater for the building's cooling requirements as well as part or all of the heating requirements.
- Repair and enhancement of pipework thermal insulation, e.g., insulating pipework through pipe supports and fitting insulation jackets to all valves and pump bodies
- Provision of a new building management system to cater for identified decarbonisation works, and to facilitate off-site remote monitoring and set point adjustment.

6.2.4.1 Air Source Heat Pump Solution

The roof of Davy building is relatively congested with specialist systems serving the laboratories which may need to be modified to provide sufficient clear space for heat pump installation, should it be located on the roof. The other consideration is that the routing of all pipework would need to be taken down to the basement level, to connect onto the primary distribution, hence new risers would need to be formed, for which there is insufficient space internally within the building to accommodate this without significant intervention.

Therefore, it is recommended that any heat pumps are located externally at ground level, and sited on a new steelwork gantry, as indicated in Figure 27. It is envisaged that this gantry would form a suitable sized base on which to mount all new air source heat pumps, that would be provided complete with attenuation packs to limit noise impact on the surrounding building's accommodation. Pipework from the air source heat pumps would then enter the existing basement boiler room, and would then connect onto existing infrastructure as appropriate.

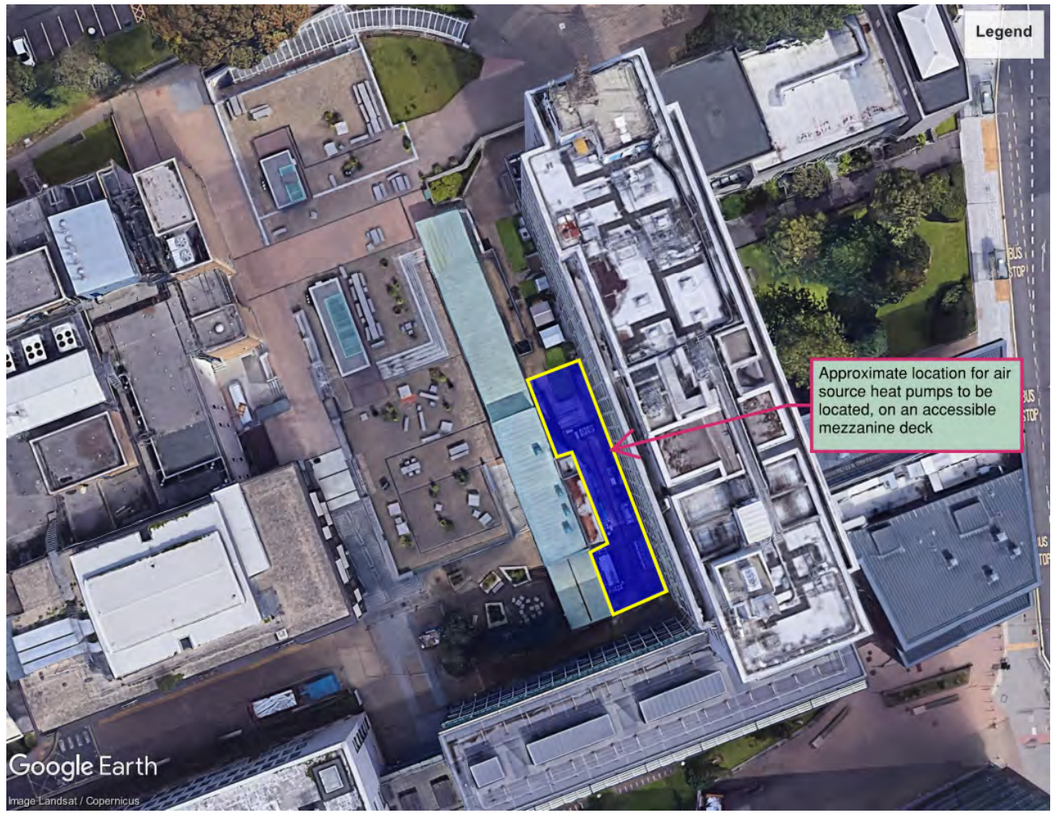


Figure 27 - Approximate location for air source heat pumps to be positioned on a new mezzanine structure

There are known services below ground in the vicinity of the proposed structure, therefore it is recommended that a full sub-site survey / ground penetrating radar survey is undertaken to ascertain the extent of existing services. They are understood to include gas, power, heat network and communications, as well as potential below ground drainage routes. Where possible the new gantry system's supports would be positioned to avoid existing services, but allowance should be made to undertake diversion works as necessary to facilitate this new structure, for which the survey works would help inform. A structural/civil engineer will need to be appointed to develop this design solution fully.

Low temperature heat pumps

If considering a wholesale replacement of the existing gas fired heating plant with a low temperature heat pump system, then this will incur significant upgrade works within the building, namely;

- New primary heating pipework
- New heating pumps and controls
- All new secondary heating pipework to be replaced (from plantroom to all final heat emitters)
- New heat emitters and coils to be replaced with larger units throughout to operate on a low temperature

The disruption to the building and its occupiers associated with the above works is massive. To try and phase the heating upgrade works around an occupied building would incur significant costs and complications that begin to make this solution unfeasible. So unless the building were to be decanted and refurbished in one go, then installing low temperature heat pumps to replace the gas fired plant is deemed to be unfeasible, and economically unjustified (see section 8 of this report).

However, the use of low temperature heat pumps as a means of pre-heating the system's water temperatures would be viable, albeit the same levels of carbon savings would not be achieved, as outlined in the previous section.

High temperature heat pumps

By installing high temperature heat pumps, the knock-on effects to the rest of the existing heating network could be significantly reduced. By installing heat pumps that can generate water at sufficient temperature to match the existing operating temperatures of the system, then this would reduce the need for any heat emitter replacements, pipework upgrades through the building, or other significant interventions. The efficiencies of high temperature heat pumps are less than low temperature ones, but they still yield carbon savings when compared to gas, and are a suitable solution for retrofitting on buildings like this.

6.2.4.2 Other Considerations

It is noted that the existing heating distribution pipework is aged and therefore may require replacement at some point in the future, which would involve significant cost and disruption. Any pipework replacement project should take into consideration futureproofing pipework and heating system design for compatibility with heat pump technologies, specifically in relation to pipework and heat emitter sizing. It is recommended they should be sized on lower flow and return temperatures to facilitate a low temperature heat pump solution being installed in the future.

In addition to the initial intervention measures suggested previously, consideration should be given to the installation of a side stream filtration system in order to improve the water quality of the circulating fluid.

Aged heating circulation pumps are likely to operate inefficiently compared to the latest generation pumping technologies and so should be replaced with high efficiency circulators to achieve electricity savings in the future.

6.2.5 Domestic hot water systems decarbonisation opportunities

The following potential opportunities were identified to potentially decarbonise the domestic hot water system:

- Provision of new high temperature domestic hot water heat pumps, to replace existing local water heaters. New pumped flow and return pipework to be routed through building, to pick up all existing hot water outlets.

However, with existing hot water generated via point of use electric water heaters with a 100% efficiency, there are zero distribution losses or inefficiencies associated with storage and pumping of hot water around a building. Although a high temperature heat pump will generate hot water more efficiently, the energy and carbon associated with storing and distributing hot water around may outweigh any benefits of the heat source efficiency, and should be carefully considered in the design. Equally, the cost and extent of intervention necessary to rout new domestic hot water around all areas of the building could make this option less appealing.

6.2.6 Renewable energy generation opportunities

A PV array could be installed on the roof of Davy building in order to provide electrical capacity for a potential heat pump installation. Coordination with existing services and any proposed heat pump installation may limit the overall extent of PV that can be installed on the available roof space.

Initial estimates on suitable, available roof space, indicate approximately 165m^2 of roof space that could be used. The roofing is flat, so angled bracketry would be required to provide a sufficient tilt angle to maximise the output from the arrays. The structural integrity of the roof to accommodate these panels would need to be investigated should the option be pursued.



Figure 28 - Davy building roof

6.2.7 Energy storage opportunities

Alongside installation of air source heat pumps, it would be proposed to install a thermal store in the basement boiler room, sized to accommodate the compressor cycle times and de-frost cycles of the air source heat pumps.

It is not currently proposed to incorporate battery storage into the building, since a carbon-saving rational for its inclusion has not been identified. However, if a substantial PV array was installed, it would be beneficial to further explore the potential benefits that the introduction of a battery storage installation could deliver.

6.2.8 Additional decarbonisation opportunities

With regard to the existing lighting systems, it is envisaged that significant energy / carbon saving could be achieved through the widespread implementation of automatic lighting controls. Additional savings could also be achieved through the conversion of all remaining fluorescent luminaires to LED (understood to represent circa 70 to 80% of the existing lighting systems.

6.2.9 Potential restrictions or constraints

6.2.9.1 Air Source Heat Pump Solution

The roof of Davy building is relatively congested with specialist systems serving the laboratories which may need to be modified to provide sufficient clear space for heat pump installation, should it be located on the roof. Roof mounted heat pumps are preferable from an acoustic and air flow perspective. They would need to be craned onto the roof, hence this will need to be considered also.

The other consideration is that the routing of all pipework would need to be taken down to the basement level, to connect onto the primary distribution, hence new risers would need to be formed, for which there is insufficient space internally within the building to accommodate this without significant intervention.

Therefore, it is recommended that any heat pumps are located externally at ground level, and sited on a new steelwork gantry, as indicated in Figure 27. It is envisaged that this gantry would form a suitable sized base on which to mount all new air source heat pumps, that would be provided complete with attenuation packs to limit noise impact on the surrounding building's accommodation. Pipework from the air source heat pumps would then enter the existing basement boiler room, and would then connect onto existing infrastructure as appropriate.

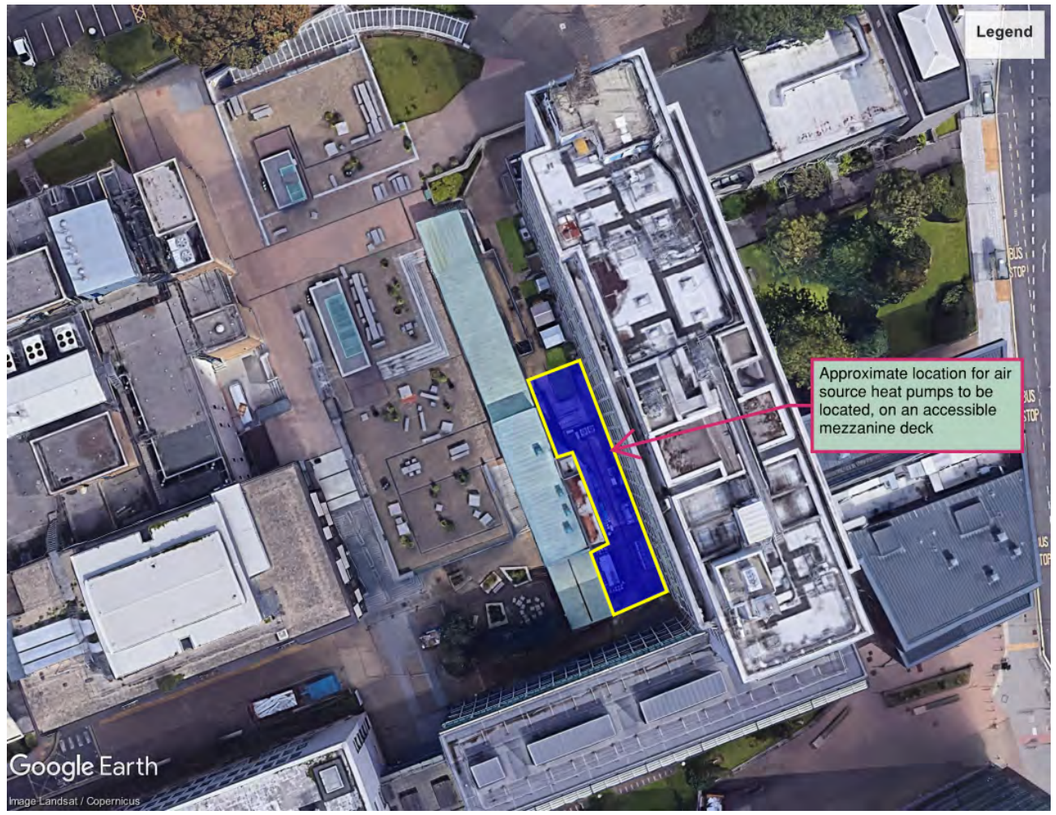


Figure 29 - Approximate location for air source heat pumps to be positioned on a new mezzanine structure

There are known services below ground in the vicinity of the proposed structure, therefore it is recommended that a full sub-site survey / ground penetrating radar survey is undertaken to ascertain the extent of existing services. They are understood to include gas, power, heat network and communications, as well as potential below ground drainage routes. Where possible the new gantry system's supports would be positioned to avoid existing services, but allowance should be made to undertake diversion works as necessary to facilitate this new structure, for which the survey works would help inform. A structural/civil engineer will need to be appointed to develop this design solution fully.

Low temperature heat pumps

If considering a wholesale replacement of the existing gas fired heating plant with a low temperature heat pump system, then this will incur significant upgrade works within the building, namely;

- New primary heating pipework
- New heating pumps and controls
- All new secondary heating pipework to be replaced (from plantroom to all final heat emitters)
- New heat emitters and coils to be replaced with larger units throughout to operate on a low temperature

The disruption to the building and its occupiers associated with the above works is massive. To try and phase the heating upgrade works around an occupied building would incur significant costs and complications that begin to make this solution unfeasible. So unless the building were to be decanted and refurbished in one go, then installing low temperature heat pumps to replace the gas fired plant is deemed to be unfeasible, and economically unjustified (see section 8 of this report).

However, the use of low temperature heat pumps as a means of pre-heating the system's water temperatures would be viable, albeit the same levels of carbon savings would not be achieved, as outlined in the previous section.

High temperature heat pumps

By installing high temperature heat pumps, the knock-on effects to the rest of the existing heating network could be significantly reduced. By installing heat pumps that can generate water at sufficient temperature to match the existing operating temperatures of the system, then this would reduce the need for any heat emitter replacements, pipework upgrades through the building, or other significant interventions. The efficiencies of high temperature heat pumps are less than low temperature ones, but they still yield carbon savings when compared to gas, and are a suitable solution for retrofitting on buildings like this.

It is noted that the current operating temperatures of the Davy heat network are at the upper end of what air source heat pumps can produce, so there may be a residual risk that some terminal heat emitters may need replacing should the ASHP not meet the current operating temperatures of the system.

Electrical loadings

In addition, the extent of spare electrical capacity (estimated to be a maximum of 280kVA for Davy building) would need to be considered, and be a significant factor in defining the maximum duty of the heat pump installation without triggering electrical infrastructure upgrades.

6.2.9.2 Alternative Hot Water Generation

With existing hot water generated via electricity with point of use water heaters, there are zero distribution losses or inefficiencies associated with storage and pumping of hot water around a building. Although a high temperature heat pump will generate hot water more efficiently, the energy and carbon associated with storing and distributing hot water around may outweigh any benefits of the heat source efficiency, and should be carefully considered in the design. Equally, having to route new domestic hot water around all areas of the building would result in significant cost

6.3 Link Building

6.3.1 Initial intervention measures

The following interventions are recommended to consider carrying out in the short term in order to inform the more detailed stages of a decarbonisation roadmap:

- Installation of further heat meters to all sub-circuits, including floor-by-floor, to air handling plant, and to areas of high energy consumption.
- Installation of electric meters to all point of use water heaters, to better monitor hot water usage and identify opportunities for further reductions.
- An LTHW water quality laboratory test of the condition of the circulating fluid, including chemical composition and presence of suspended solids/corrosion
- non-destructive testing of the existing pipework to assess its thickness in case of corrosion
- installation of a corrosion monitoring system
- commissioning of a thermographic survey of the building fabric's thermal performance to ascertain any specific areas on which to make a focus.

6.3.2 Building fabric decarbonisation opportunities

The following potential fabric improvement interventions have been identified for exploration at the Link building:

- Installation of new and/or additional roof insulation. In order to assess the impact that this measure would have, the current roof insulation provision will need to be established.

It is recommended to consider commissioning a thermographic survey to identify in detail the areas where meaningful improvements could be made to the thermal performance of the building envelope, and engaging an architect to develop design proposals to implement such improvements.

6.3.3 Ventilation systems decarbonisation opportunities

The majority of ventilation systems in the Link building can benefit from enhanced controls. These would include demand controlled ventilation, and optimisation of systems via the BMS.

6.3.4 Heating & cooling systems decarbonisation opportunities

The following potential opportunities were identified to decarbonise the heating system, if treated as a standalone building (i.e. not taking benefits of any interventions to the existing heat network fed from Davy Building):

- Installation of motorised control valves to heat emitters, room air temperature sensors and zoned controls to allow each room to be individually temperature controlled with its own adjustable timeclock and temperature set back
- Integration of heat pump technologies to support the Link Building in isolation, as below options
    - Integration of low temperature air source heat pumps into the primary flow and return circuits that are connected to the existing heat network. Disconnect Link Building from the heat network. New heat pumps to provide the full heating load of the building. This option would require wholesale replacement of the entire heating system within the building, including heating pipework and emitters to ensure compatibility with heat pump flow temperatures.
    - Integration of high temperature air source heat pumps into the primary flow and return circuits that are connected to the existing heat network. Disconnect Link Building from the heat network. New heat pumps to provide the full heating load of the building. As operating temperatures would be elevated, the high temperature heat pumps would offer a direct replacement for the existing heat network (i.e. retain all internal heat emitter sizes and associated pipework).
- Repair and enhancement of pipework thermal insulation, e.g., insulating pipework through pipe supports and fitting insulation jackets to all valves and pump bodies
- Provision of a new building management system to cater for identified decarbonisation works, and to facilitate off-site remote monitoring and set point adjustment.

6.3.4.1 Other Considerations

It is noted that the existing heating distribution pipework is aged and therefore may require replacement at some point in the future, which would involve significant cost and disruption. Any pipework replacement project should take into consideration futureproofing pipework and heating system design for compatibility with heat pump technologies, specifically in relation to pipework and heat emitter sizing. It is recommended they should be sized on lower flow and return temperatures to facilitate a low temperature heat pump solution being installed in the future.

In addition to the initial intervention measures suggested previously, consideration should be given to the installation of a side stream filtration system in order to improve the water quality of the circulating fluid, whether that's located in Link or within the Davy boiler room.

6.3.5 Domestic hot water systems decarbonisation opportunities

The following potential opportunities were identified to potentially decarbonise the domestic hot water system:

- Provision of new high temperature domestic hot water heat pumps, to replace existing local water heaters. New pumped flow and return pipework to be routed through building, to pick up all existing hot water outlets.

However, with existing hot water generated via point of use electric water heaters with a 100% efficiency, there are zero distribution losses or inefficiencies associated with storage and pumping of hot water around a building. Although a high temperature heat pump will generate hot water more efficiently, the energy and carbon associated with storing and distributing hot water around may outweigh any benefits of the heat source efficiency, and should be carefully considered in the design. Equally, the cost and extent of intervention necessary to rout new domestic hot water around all areas of the building could make this option less appealing.

6.3.6 Renewable energy generation opportunities

A PV array could be installed on the roof of Link building in order to provide electrical capacity for a potential heat pump installation. Coordination with existing services and any proposed heat pump installation may limit the overall extent of PV that can be installed on the available roof space.

Initial estimates on suitable, available roof space, indicate approximately 280m^2 of roof space that could be used. The roofing is flat, so angled bracketry would be required to provide a sufficient tilt angle to maximise the output from the arrays. The structural integrity of the roof to accommodate these panels would need to be investigated should the option be pursued.



Figure 30 - Link building roof

6.3.7 Energy storage opportunities

Alongside installation of air source heat pumps, it would be proposed to install a thermal store, sized to accommodate the compressor cycle times and de-frost cycles of the air source heat pumps. If installing heat pumps on the roof of Link, then this store would need to be located in a suitable environment, preferably a weatherproof construction on the roof.

It is not currently proposed to incorporate battery storage into the building, since a carbon-saving rational for its inclusion has not been identified. However, if a substantial PV array was installed, it would be beneficial to further explore the potential benefits that the introduction of a battery storage installation could deliver.

6.3.8 Additional decarbonisation opportunities

With regard to the existing lighting systems, it is envisaged that significant energy / carbon saving could be achieved through the widespread implementation of automatic lighting controls. Additional savings could also be achieved through the conversion of all remaining fluorescent luminaires to LED (understood to represent circa 100% of the existing lighting systems).

6.3.9 Potential restrictions or constraints

A roof top location for heat pumps would be preferable as from an acoustic and air flow perspective. Heat pumps installed on the roof would need to be craned into place. The roof structure would also require validating that it could accommodate the additional load of heat pumps and the thermal store(s).

Locating heat pumps on the roof would require additional risers throughout the building to link up with the existing infrastructure in the basement plantrooms. Impact on room layouts at each level will need to be considered, along with how the risers could be formed. There may be some structural and spatial impacts that need further investigation.

In addition, the extent of spare electrical capacity (estimated to be a maximum of tbc kVA for Link building) would need to be considered, and be a significant factor in defining the maximum duty of the heat pump installation without triggering electrical infrastructure upgrades.

It is noted that the current operating temperatures of the Davy heat network are at the upper end of what air source heat pumps can produce, so there may be a residual risk that some terminal heat emitters may need replacing should the ASHP not meet the current operating temperatures of the system.

6.4 Smeaton Building

6.4.1 Initial intervention measures

The following interventions are recommended to consider carrying out in the short term in order to inform the more detailed stages of a decarbonisation roadmap:

- Installation of further heat meters to all sub-circuits, including floor-by-floor, to air handling plant, and to areas of high energy consumption.
- Installation of electric meters to all point of use water heaters, to better monitor hot water usage and identify opportunities for further reductions.
- An LTHW water quality laboratory test of the condition of the circulating fluid, including chemical composition and presence of suspended solids/corrosion
- non-destructive testing of the existing pipework to assess its thickness in case of corrosion
- installation of a corrosion monitoring system
- commissioning of a thermographic survey of the building fabric's thermal performance to ascertain any specific areas on which to make a focus.

6.4.2 Building fabric decarbonisation opportunities

The following potential fabric improvement interventions have been identified for exploration at Smeaton building:

- Installation of new and/or additional roof insulation. In order to assess the impact that this measure would have, the current roof insulation provision will need to be established.
- Installation of double glazing on the remaining single glazed windows (noting that double glazing has already been fitted in most of the Occupied rooms)
- Sealing of existing windows where they are draughty and have not already been sealed

It is recommended to consider commissioning a thermographic survey to identify in detail the areas where meaningful improvements could be made to the thermal performance of the building envelope, and engaging an architect to develop design proposals to implement such improvements.

6.4.3 Ventilation systems decarbonisation opportunities

6.4.4 Heating & cooling systems decarbonisation opportunities

The following potential opportunities were identified to decarbonise the heating system, if treated as a standalone building (i.e. not taking benefits of any interventions to the existing heat network fed from Davy Building):

- Installation of motorised control valves to heat emitters, room air temperature sensors and zoned controls to allow each room to be individually temperature controlled with its own adjustable timeclock and temperature set back
- Integration of heat pump technologies to support the Smeaton Building in isolation, as below options
    - Integration of low temperature air source heat pumps into the primary flow and return circuits that are connected to the existing heat network. Disconnect Smeaton Building from the heat network. New heat pumps to provide the full heating load of the building. This option would require wholesale replacement of the entire heating system within the building, including heating pipework and emitters to ensure compatibility with heat pump flow temperatures.
    - Integration of high temperature air source heat pumps into the primary flow and return circuits that are connected to the existing heat network. Disconnect Smeaton Building from the heat network. New heat pumps to provide the full heating load of the building. As operating temperatures would be elevated, the high temperature heat pumps would offer a direct replacement for the existing heat network (i.e. retain all internal heat emitter sizes and associated pipework).
- Repair and enhancement of pipework thermal insulation, e.g., insulating pipework through pipe supports and fitting insulation jackets to all valves and pump bodies
- Provision of a new building management system to cater for identified decarbonisation works, and to facilitate off-site remote monitoring and set point adjustment.

6.4.4.1 Other Considerations

It is noted that the existing heating distribution pipework is aged and therefore may require replacement at some point in the future, which would involve significant cost and disruption. Any pipework replacement project should take into consideration futureproofing pipework and heating system design for compatibility with heat pump technologies, specifically in relation to pipework and heat emitter sizing. It is recommended they should be sized on lower flow and return temperatures to facilitate a low temperature heat pump solution being installed in the future.

In addition to the initial intervention measures suggested previously, consideration should be given to the installation of a side stream filtration system in order to improve the water quality of the circulating fluid, whether that's located in Smeaton or within the Davy boiler room.

6.4.5 Domestic hot water systems decarbonisation opportunities

The following potential opportunities were identified to potentially decarbonise the domestic hot water system:

- Provision of new high temperature domestic hot water heat pumps, to replace existing local water heaters. New pumped flow and return pipework to be routed through building, to pick up all existing hot water outlets.

However, with existing hot water generated via point of use electric water heaters with a 100% efficiency, there are zero distribution losses or inefficiencies associated with storage and pumping of hot water around a building. Although a high temperature heat pump will generate hot water more efficiently, the energy and carbon associated with storing and distributing hot water around may outweigh any benefits of the heat source efficiency, and should be carefully considered in the design. Equally, the cost and extent of intervention necessary to rout new domestic hot water around all areas of the building could make this option less appealing.

6.4.6 Renewable energy generation opportunities

A PV array could be installed on the roof of Smeaton in order to provide electrical capacity for a potential heat pump installation. Coordination with existing services and any proposed heat pump installation may limit the overall extent of PV that can be installed on the available roof space.

Initial estimates on suitable, available roof space, indicate approximately 540m^2 of roof space that could be used. The roofing is flat, so angled bracketry would be required to provide a sufficient tilt angle to maximise the output from the arrays. The structural integrity of the roof to accommodate these panels would need to be investigated should the option be pursued.



Figure 31 - Smeaton building roof

6.4.7 Energy storage opportunities

Alongside installation of air source heat pumps, it would be proposed to install a thermal store in the ground floor plant room, sized to accommodate the compressor cycle times and de-frost cycles of the air source heat pumps.

It is not currently proposed to incorporate battery storage into the building, since a carbon-saving rational for its inclusion has not been identified. However, if a substantial PV array was installed, it would be beneficial to further explore the potential benefits that the introduction of a battery storage installation could deliver.

6.4.8 Additional decarbonisation opportunities

With regard to the existing lighting systems, it is envisaged that significant energy / carbon saving could be achieved through the widespread implementation of automatic lighting controls. Additional savings could also be achieved through the conversion of all remaining fluorescent luminaires to LED (understood to represent circa 10 to 20% of the existing lighting systems.

6.4.9 Potential restrictions or constraints

The form of the roof and extent of existing roof mounted services may limit the extent of heat pump that can be installed. It may be necessary to adapt some existing services to increase available space for heat pump installations.

Locating heat pumps on the roof would require additional riser throughout the building to link up with the existing infrastructure in the basement plantrooms. Impact on room layouts at each level will need to be considered, along with the impact on forming new structural openings etc.

A roof top location for heat pumps would be preferable from an acoustic and air flow perspective. Heat pumps installed on the roof would need to be craned into place.

In addition, the extent of spare electrical capacity (estimated to be a maximum of 160kVA for Smeaton) would need to be considered, and be a significant factor in defining the maximum duty of the heat pump installation without triggering electrical infrastructure upgrades.

It is noted that the current operating temperatures of the Davy heat network are at the upper end of what air source heat pumps can produce, so there may be a residual risk that some terminal heat emitters may need replacing should the ASHP not meet the current operating temperatures of the system.

6.5 Scott Building

6.5.1 Initial intervention measures

The following interventions are recommended to consider carrying out in the short term in order to inform the more detailed stages of a decarbonisation roadmap:

- Installation of further heat meters to all sub-circuits, including floor-by-floor, to air handling plant, and to areas of high energy consumption.
- Installation of electric meters to all point of use water heaters, to better monitor hot water usage and identify opportunities for further reductions.
- An LTHW water quality laboratory test of the condition of the circulating fluid, including chemical composition and presence of suspended solids/corrosion
- non-destructive testing of the existing pipework to assess its thickness in case of corrosion
- installation of a corrosion monitoring system
- commissioning of a thermographic survey of the building fabric's thermal performance to ascertain any specific areas on which to make a focus.

6.5.2 Building fabric decarbonisation opportunities

The following potential fabric improvement interventions have been identified for exploration at the Scott building:

- Installation of internal insulation to the external walls.
- Installation of new and/or additional roof insulation. In order to assess the impact that this measure would have, the current roof insulation provision will need to be established.
- Installation of double or secondary glazing on the remaining single glazed windows (noting that secondary glazing has already been fitted in most of the north facing rooms)
- Sealing of existing windows where they are draughty and have not already been sealed

It is recommended to consider commissioning a thermographic survey to identify in detail the areas where meaningful improvements could be made to the thermal performance of the building envelope, and engaging an architect to develop design proposals to implement such improvements.

6.5.3 Ventilation systems decarbonisation opportunities

Ventilation systems in Scott are thought to be approximately 15 years old, and range in size and duty. There is likely to be an opportunity to improve the current performance of the ventilation systems through a number of measures, including;

- Providing demand controlled ventilation to rooms that are mechanically ventilated, to reduce or turn off ventilation when not required
- Replacement of old fans and motors with newer, more efficient units

6.5.4 Heating & cooling systems decarbonisation opportunities

The following potential opportunities were identified to decarbonise the heating system:

- Installation of motorised control valves to heat emitters, room air temperature sensors and zoned controls to allow each room to be individually temperature controlled with its own adjustable timeclock and temperature set back
- Integration of heat pump technologies, as below options
    - Integration of low temperature air source heat pumps into the secondary circuit returns to the boiler system, to pre-heat when the circuit temperatures are sufficiently reduced via weather compensation. Note this option will not fully decarbonise the heating system as gas fired boiler plant will still be required to meet peak loads however a significant proportion of the heat pumps will be sized to cater for a significant portion of the heating demand.
    - Integration of high temperature air source heat pumps into the secondary circuit returns to the boiler system, to pre-heat when the outdoor air temperature is mild enough to allow a high temperature air source heat pump to operate at a sufficiently high coefficient of performance (COP) to reduce carbon emissions in comparison to gas boilers. Note this option will not fully decarbonise the heating system as gas fired boiler plant will still be required to meet peak loads however a significant proportion of the heat pumps will be sized to cater for a significant portion of the heating demand.
    - Integration of low temperature air source heat pumps into the secondary circuit returns to the boiler system, to heat as much as possible, with boiler top-up, alongside replacement of all heat emitters to operate at low temperatures. Note this option will not fully decarbonise the heating system as gas fired boiler plant will still be required to meet peak loads however a significant proportion of the heat pumps will be sized to cater for a significant portion of the heating demand.
    - Wholesale replacement of gas fired heat generating plant with electric driven heat pump technologies. This option would require wholesale replacement of the entire heating system including heating pipework and emitters to ensure compatibility with heat pump flow temperatures, should low temperature heat pumps be selected. As such the disruption arising from the implementation of this option will be significant and therefore this option becomes particularly attractive if the whole building is considered for refurbishment. However, if minimal intervention is deemed the more appropriate solution, then high temperature heat pumps could be installed to replace the gas fired plant, by providing flow temperatures at the same condition as the gas fired solutions. There would be a reduction in operating efficiencies of high temperature vs. low temperature heat pumps, but they would still attract a very good carbon reduction when compared to gas fired solutions.
- Repair and enhancement of pipework thermal insulation, e.g., insulating pipework through pipe supports and fitting insulation jackets to all valves and pump bodies
- Provision of a new building management system to cater for identified decarbonisation works, and to facilitate off-site remote monitoring and set point adjustment.

6.5.4.1 Other Considerations

It is noted that the existing heating distribution pipework is aged and therefore may require replacement at some point in the future, which would involve significant cost and disruption. Any pipework replacement project should take into consideration futureproofing pipework and heating system design for compatibility with heat pump technologies, specifically in relation to pipework and heat emitter sizing. It is recommended they should be sized on lower flow and return temperatures to facilitate a low temperature heat pump solution being installed in the future.

In addition to the initial intervention measures suggested previously, consideration should be given to the installation of a side stream filtration system in order to improve the water quality of the circulating fluid.

6.5.5 Domestic hot water systems decarbonisation opportunities

The following potential opportunities were identified to potentially decarbonise the domestic hot water system:

- Provision of new high temperature domestic hot water heat pumps, to replace existing local water heaters. New pumped flow and return pipework to be routed through building, to pick up all existing hot water outlets.

However, with existing hot water generated via point of use electric water heaters with a 100% efficiency, there are zero distribution losses or inefficiencies associated with storage and pumping of hot water around a building. Although a high temperature heat pump will generate hot water more efficiently, the energy and carbon associated with storing and distributing hot water around may outweigh any benefits of the heat source efficiency, and should be carefully considered in the design. Equally, the cost and extent of intervention necessary to rout new domestic hot water around all areas of the building could make this option less appealing.

6.5.6 Renewable energy generation opportunities

A PV array could be installed on the south facing pitched elements of the roofs of the Scott building in order to provide electrical capacity for a potential heat pump installation. However, it should be noted that there may

be some issues with regards to Planning, as although the building is not understood to be Listed, then there could be some objections to materially altering the appearance of the building.

For the purpose of the assessment, an initial assessment of available roof space suggests up to 346m^2 could be used. The structural integrity of the roof to accommodate these panels would need to be investigated should the option be pursued.



Figure 32 - Scott building roof

6.5.7 Energy storage opportunities

Alongside installation of air source heat pumps, it would be proposed to install a thermal store in the basement boiler room, sized to accommodate the compressor cycle times and de-frost cycles of the air source heat pumps.

It is not currently proposed to incorporate battery storage into the building, since a carbon-saving rational for its inclusion has not been identified. However, if a substantial PV array was installed, it would be beneficial to further explore the potential benefits that the introduction of a battery storage installation could deliver.

6.5.8 Additional decarbonisation opportunities

With regard to the existing lighting systems, it is envisaged that significant energy / carbon saving could be achieved through the widespread implementation of automatic lighting controls. Additional savings could also be achieved through the conversion of all remaining fluorescent luminaires to LED (understood to represent circa 60 to 70% of the existing lighting systems.

6.5.9 Potential restrictions or constraints

Due to the type of roof (pitched), then any form of heat pumps would need to be sited externally and at ground level. This would most likely be within the waste storage yard to the south of the building where there is currently very little available space. Allowance would need to be paid to enclose the heat pumps within an enclosure, that was sympathetic to the building, and provided good air flow around the heat pumps. Equally, piped connections would need to be taken through to the basement of the existing building, to connect onto the primary heating pipework currently served from the boilers.

The extent of spare electrical capacity (estimated to be a maximum of 150kVA for Scott building) would need to be considered, and be a significant factor in defining the maximum duty of the heat pump installation without triggering electrical infrastructure upgrades.

6.6 Marine Building

6.6.1 Initial intervention measures

The following interventions are recommended to consider carrying out in the short term in order to inform the more detailed stages of a decarbonisation roadmap:

- installation of a corrosion monitoring system
- commissioning of a thermographic survey of the building fabric's thermal performance to ascertain any specific areas on which to make a focus.

6.6.2 Building fabric decarbonisation opportunities

Due to the age of the building, there are limited opportunities to improve on the building fabric. However, it is recommended to consider commissioning a thermographic survey to identify in detail the areas where meaningful improvements could be made to the thermal performance of the building envelope, and engaging an architect to develop design proposals to implement such improvements.

6.6.3 Ventilation systems decarbonisation opportunities

There is opportunity to review the accuracy of control of the natural ventilation systems within the building, to ensure that any associated heating loads are minimised, whilst maintaining adequate internal air quality. Whilst each room appeared to be controlling to a specific set of parameters, an interrogation of the BMS to fully understand the set points and associated performance could yield some reduction in energy usage.

The single air handling unit serving the tank hall appears to be as efficient as is reasonable, and due to its age, there are unlikely any significant intervention measures that could be incorporated to generate a reduction in carbon associated with its use.

6.6.4 Heating & cooling systems decarbonisation opportunities

The following potential opportunities were identified to decarbonise the heating system, if treated as a standalone building (i.e. not taking benefits of any interventions to the existing heat network fed from Davy Building):

- Installation of motorised control valves to heat emitters, room air temperature sensors and zoned controls to allow each room to be individually temperature controlled with its own adjustable timeclock and temperature set back
- Integration of heat pump technologies to support the Marine Building in isolation, as below options
    - Integration of low temperature air source heat pumps into the primary flow and return circuits that are connected to the existing heat network. Disconnect Marine Building from the heat network. New heat pumps to provide the full heating load of the building. This option would require wholesale replacement of the entire heating system within the building, including heating pipework and emitters to ensure compatibility with heat pump flow temperatures.
    - Integration of high temperature air source heat pumps into the primary flow and return circuits that are connected to the existing heat network. Disconnect Marine Building from the heat network. New heat pumps to provide the full heating load of the building. As operating temperatures would be elevated, the high temperature heat pumps would offer a direct replacement for the existing heat network (i.e. retain all internal heat emitter sizes and associated pipework).

Due to the location of the building, and limited space externally to the building, locations for heat pumps would be limited to the rooftop, or the mezzanine deck on which the air handling unit is located. Both would be viable, although structures would need to be checked in further detail to ascertain whether any structural upgrades would be required. The preference, from an ease perspective, would be to locate the heat pumps on the existing flat roof.

6.6.4.1 Other Considerations

In addition to the initial intervention measures suggested previously, consideration should be given to the installation of a side stream filtration system in order to improve the water quality of the circulating fluid, whether that's located in Marine or within the Davy boiler room.

6.6.5 Domestic hot water systems decarbonisation opportunities

The current hot water generation is primarily provided via a solar thermal array at roof level, that feeds into a domestic hot water calorifier in the basement. What we can see from the metered data is that periodically, the LTHW system (fed from Davy building) contributes heat to the system, presumably to raise the water temperature. Equally, the electric immersion also operates several times a day to raise the water temperature, even over the peak of summer months. The operation of the immersion element should be checked with regards to its controls, to ensure it is not operating unnecessarily, along with the contribution from the LTHW system.

There is a remaining potential to then increase the solar array slightly to help reduce the reliance upon both the LTHW system, and the electric immersion. As a cautionary note, the addition of solar panels needs to be carefully considered with the actual hot water usage profiles of the building, particularly in summertime, to ensure the whole system operates correctly.

6.6.6 Renewable energy generation opportunities

A PV array could be installed on the roof of the Marine building in order to provide electrical capacity for a potential heat pump installation. Whilst there are limited services at roof level, the flat roof sits behind a parapet, and there are a number of ventilation stacks that protrude above the roof, as seen in Figure 33. These all produce shading, which would limit the extent of PV array that could actually be installed on the roof.



Figure 33 - Marine building roof

Initial estimates on suitable, available roof space, indicate approximately 240m^2 of roof space that could be used. However, a detailed shading study should be undertaken should this option be considered further.

6.6.7 Energy storage opportunities

Alongside installation of air source heat pumps, it would be proposed to install a thermal store in the basement plant room, sized to accommodate the compressor cycle times and de-frost cycles of the air source heat pumps.

It is not currently proposed to incorporate battery storage into the building, since a carbon-saving rational for its inclusion has not been identified. However, if a substantial PV array was installed, it would be beneficial to further explore the potential benefits that the introduction of a battery storage installation could deliver.

6.6.8 Additional decarbonisation opportunities

With regard to the existing lighting systems, it is envisaged that significant energy / carbon saving could be achieved through the widespread implementation of automatic lighting controls. Additional savings could also be achieved through the conversion of all remaining fluorescent luminaires to LED (understood to represent circa 30 to 40% of the existing lighting systems.

6.6.9 Potential restrictions or constraints

The structural makeup of the roof may limit the extent of mounting heat pumps at this level, based on their weight loading. Equally, consideration would be needed to avoid introducing vibration to the concrete structure, that could emanate through the building, hence sufficient AV mountings on the units would be required.

Locating heat pumps on the roof would require additional routes through the building to take pipework to the basement plantroom, although the riser provision within the building is generous, hence unlikely to cause any major issues., bar some minor Builderswork.

Heat pumps installed on the roof would need to be craned into place.

Current access to the roof is limited to a single small door. Consideration should be paid as to whether this is adequate from a maintenance perspective should heat pumps be located at this level, and how parts and spares would be transported to roof level.

In addition, the extent of spare electrical capacity (estimated to be a maximum of 265kVA for the Marine building) would need to be considered and be a significant factor in defining the maximum duty of the heat pump installation without triggering electrical infrastructure upgrades.

6.7 The House

6.7.1 Initial intervention measures

The following interventions are recommended to consider carrying out in the short term in order to inform the more detailed stages of a decarbonisation roadmap:

- installation of a corrosion monitoring system
- commissioning of a thermographic survey of the building fabric's thermal performance to ascertain any specific areas on which to make a focus.

6.7.2 Building fabric decarbonisation opportunities

Due to the age of the building, there are limited opportunities to improve on the building fabric. However, it is recommended to consider commissioning a thermographic survey to identify in detail the areas where meaningful improvements could be made to the thermal performance of the building envelope, and engaging an architect to develop design proposals to implement such improvements.

6.7.3 Ventilation systems decarbonisation opportunities

There is opportunity to review the accuracy of control of the natural ventilation systems within the building, to ensure that any associated heating loads are minimised, whilst maintaining adequate internal air quality. Whilst each room appeared to be controlling to a specific set of parameters, an interrogation of the BMS to fully understand the set points and associated performance could yield some reduction in energy usage.

The air handling units within the building are controlled via user controllers. These should be reviewed to ensure that there are sufficient overrides or controls to prevent them running unnecessarily, or out-of-hours. Due to the age of the systems through, they are unlikely to yield any significant savings from much further intervention.

6.7.4 Heating & cooling systems decarbonisation opportunities

The following potential opportunities were identified to decarbonise the heating system, if treated as a standalone building (i.e. not taking benefits of any interventions to the existing heat network fed from Davy Building):

- Installation of motorised control valves to heat emitters, room air temperature sensors and zoned controls to allow each room to be individually temperature controlled with its own adjustable timeclock and temperature set back
- Integration of heat pump technologies to support the The House in isolation, as below options
    - Integration of low temperature air source heat pumps into the primary flow and return circuits that are connected to the existing heat network. Disconnect The House from the heat network. New heat pumps to provide the full heating load of the building. This option would require wholesale replacement of the entire heating system within the building, including heating pipework and emitters to ensure compatibility with heat pump flow temperatures.
    - Integration of high temperature air source heat pumps into the primary flow and return circuits that are connected to the existing heat network. Disconnect The House from the heat network. New heat pumps to provide the full heating load of the building. As operating temperatures would be elevated, the high temperature heat pumps would offer a direct replacement for the existing heat network (i.e. retain all internal heat emitter sizes and associated pipework).

Due to the location of the building, and no available roof space on which to house heat pumps, there are very limited opportunities to install heat pumps without having a wider knock-on effect on the campus. There is an area of grass to the north of the building, but this is understood to be ear-marked for a future project / building extension.

Therefore, any heat pump solution would need to be fed into the heat network back at Davy Building.

In consideration of the disruption arising from replacement of the entire heating system serving the House, it is not currently envisaged that a wholesale replacement of the gas fired heating plant with air source heat pumps would be feasible or economically justified unless the whole building is to be refurbished.

It is recommended that any pipework replacement project should take into consideration futureproofing pipework and heating system design for compatibility with heat pump technologies, specifically in relation to pipework and heat emitter sizing.

In addition to the initial intervention measures suggested previously, consideration should be given to the installation of a side stream filtration system in order to improve the water quality of the circulating fluid.

6.7.5 Domestic hot water systems decarbonisation opportunities

The following potential opportunities were identified to decarbonise the domestic hot water system:

- Provision of new high temperature domestic hot water heat pumps, to replace existing water heaters local electric water heaters.

6.7.6 Renewable energy generation opportunities

A PV array could be installed on the roof of the House in order to provide electrical capacity for a potential heat pump installation. Coordination with existing services and any proposed heat pump installation may limit the overall extent of PV that can be installed on the available roof space.

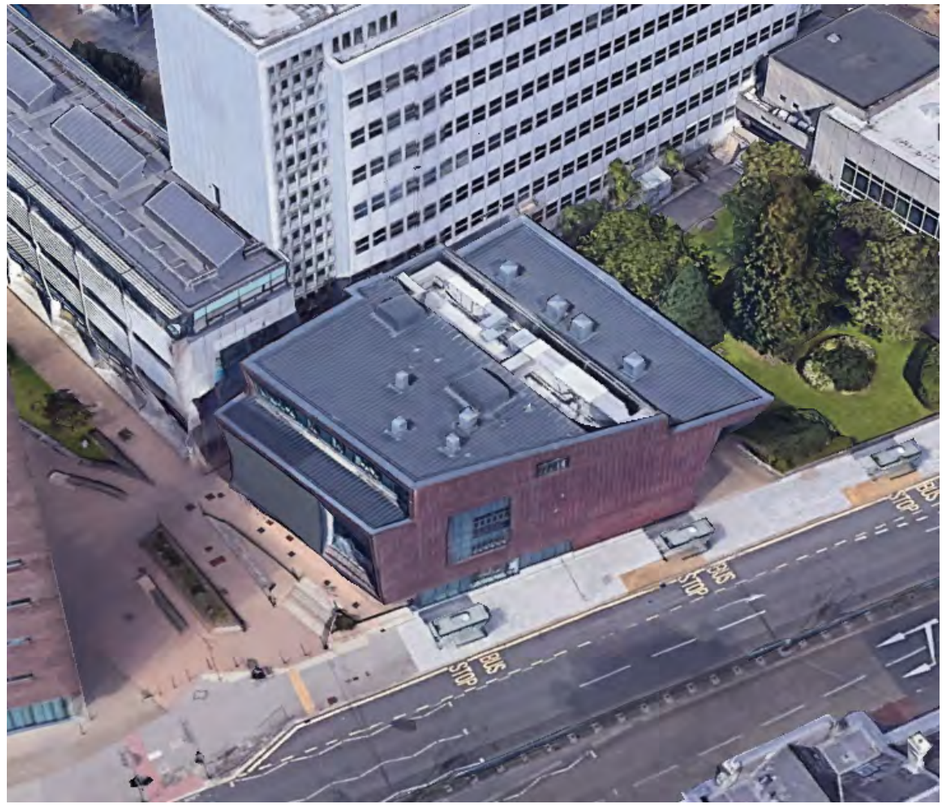


Figure 34 - The House building roof

6.7.7 Energy storage opportunities

Alongside installation of air source heat pumps, it would be proposed to install a thermal store in the third-floor plant room, sized to accommodate the compressor cycle times and de-frost cycles of the air source heat pumps.

It is not currently proposed to incorporate battery storage into the building, since a carbon-saving rational for its inclusion has not been identified. However, if a substantial PV array was installed, it would be beneficial to further explore the potential benefits that the introduction of a battery storage installation could deliver.

6.7.8 Additional decarbonisation opportunities

With regard to the existing lighting systems, it is envisaged that significant energy / carbon saving could be achieved through the widespread implementation of automatic lighting controls. It is understood that the existing lighting is high efficiency LED fittings already and so there is minimal scope for additional savings by upgrading light fittings.

6.7.9 Potential restrictions or constraints

The main restriction on this building is the lack of available space at roof level, or around the building, in which to house new external equipment. Whilst the roof could potentially accommodate some lightweight PV panels, there is insufficient space for heat pumps to be mounted up here.

If PVs were to be installed on the roof, suitable access and fall protection measures would need to be considered.

In addition, the extent of spare electrical capacity (estimated to be a maximum of 160kVA for the House building) would need to be considered, and be a significant factor in defining the maximum duty of the heat pump installation without triggering electrical infrastructure upgrades.

It is noted that the current operating temperatures of the Davy heat network are at the upper end of what air source heat pumps can produce, so there may be a residual risk that some terminal heat emitters may need replacing should the ASHP not meet the current operating temperatures of the system.

7. Decarbonisation Intervention Assessment Methodology

7.1 Overview

This section of the report summarises the assessment methodology adopted in order to estimate the impact to the energy and carbon footprint of each identified decarbonisation intervention.

Each intervention has been assessed in isolation without consideration of impact from other potential interventions in respect of either feasibility or decarbonisation. Adoption of multiple interventions will require assessment of all interventions combined.

BEIS carbon factors have been used in all calculations. To include the effect of continued decarbonisation of the electricity grid an average carbon factor for the period 2022 – 2036 has been used.

- Gas – 0.184 kg CO2 / kWh
- Electricity – 0.146 kg CO2 / kWh

7.2 Building fabric decarbonisation opportunities

7.2.1 Provision of additional fabric thermal insulation

For each building, a percentage reduction in heat loss was assessed from existing and target u-values and external temperature weather data. The percentage reduction was then applied to annual heat meter data to assess reduction heating demand.

Due to the variation in ages of the building stock within scope of this plan details of existing building fabric thermal performance properties are not accurately known. For buildings without accurate building fabric information an assessment has been made of fabric u-values from assumed construction build up.

7.2.2 Provision of secondary glazing

For each building, a percentage reduction in heat loss was assessed from existing and target u-values and external temperature weather data. The percentage reduction was then applied to annual heat meter data to assess reduction heating demand.

Due to the variation in ages of the building stock within scope of this plan details of existing window thermal performance properties are not accurately known. For buildings without accurate building fabric information an assessment has been made of fabric u-values from assumed construction build up.

7.2.3 Provision of draughtproofing to windows

For each building, a percentage reduction in heat loss was assessed from existing and target infiltration rates and external temperature weather data. The percentage reduction was then applied to annual heat meter data to assess reduction heating demand.

Determination of a building's air change rate is difficult to verify so each building's infiltration rate was estimated by applying an appropriate air change rate for the building's approximate year of construction, with an allowance for any observed fabric upgrades.

7.2.4 Remedial works resulting from thermographic survey

By undertaking a thermographic survey of buildings, it is possible to identify areas of significant weakness in buildings and their services that are losing high levels of heat. By knowing where these areas are, then focussed remedial works can be undertaken to try and reduce the losses, to ultimately lead to a better performing heating /cooling system, thus saving energy and reducing carbon. A survey of the external façade, and all main plant distribution routes would be recommended to identify areas of greatest opportunity.

7.3 Heat pump integration decarbonisation opportunities

7.3.1 Provision of ASHP installation in lead heat source capacity

To estimate the monthly gas usage associated with this system, the summation of heating loads for the five buildings in question that are on this network can be divided by the heat network system efficiency. The heat network system efficiency can be estimated by apportioning each heat source efficiency to the load contribution of that heat source. These values can be used for benchmarking against improvements.

The typical seasonal coefficient of performance (SCOP) for a heat pump system can be determined using typical manufacturers data and made specific by using the local outdoor air temperatures taken from the University of Plymouth records. Applying these SCOP values to the monthly demand values can determine the required electrical load, and the CO2 savings by applying the relevant carbon factors to the new fuel load.

Manufacturer's data will also be used to determine the ASHP SCOP at various operating temperatures to establish the impact of this on CO2 savings and cost to implement utilising the existing distribution and heat emitters where this is viable. A high temperature ASHP system would be equivalent to a direct replacement of the gas fired heat sources whereas a low temperature system may require upgrades to distribution pipework and heat emitters, or a bivalent system where smaller gas fired plant further uplifts the temperature to be compatible with the existing network.

Where a bivalent heating system is considered, this will be based on the ASHP plant supplying a base load. Gas fired plant will be assumed to be sized as a percentage load of the peak demand. The annual use of this will be estimated to be when the external temperature drops below a given value, say 5°C. In this way site specific data will feed into the estimation to improve accuracy of the calculation.

7.3.2 Provision of GSHP installation in lead heat source capacity

Estimating the performance and carbon savings for a ground source heat pump option will be as per the above section 7.3.1, but with equipment performance efficiencies for specific GSHP units. An assessment will also be undertaken to establish the ground area required to size and locate boreholes this will be done on a no. boreholes/kW/ m^2. A previous study has provided a similar assessment for the University of Plymouth and will feed into this calculation.

7.3.3 Domestic hot water generation using ASHPs

To assess the carbon reduction of domestic hot water generation via high temperature heat pumps, each building's annual heat demand for domestic hot water generation was estimated or derived from metering data.

As many of the buildings utilise local standalone electric water heaters, in use data for the domestic hot water is not available for all assessments. Where in use data from heat / sub meters was unavailable the building's annual heat demand for domestic hot water was estimated using established design benchmarks for the building typology. Local electric water heaters are assumed to be 100% efficient.

For buildings with centralised domestic hot water systems complete with sufficient sub metering information a more accurate existing hot water annual heat demand was available. Gross heating demand was assessed by applying an allowance for distribution heat losses, pumping power and heat generator efficiency, where applicable.

Once each building's annual domestic hot water heating load was established, the reduction achieved by adoption of high temperature heat pumps was assessed by applying an appropriate CoP. An allowance was applied for distribution heat losses and pumping power, where applicable.

7.3.4 Provision of ASHP / GSHP installation to fully offset fossil fuel consumption

As discussed in 7.3.1. This estimation will look at the feasibility of the GSHP option in the first instance as this technology will yield the highest efficiencies. Since there are physical limitations with the space associated with boreholes and prohibitive costs associates with such an installation, once the most economical options for GSPHs have been considered the remaining, outstanding loads will be met by ASHP plant.

7.3.5 Replacement of Split DX cooling systems

The total cooling load for each building was estimated from meter data if available or in the absence of metering data benchmarking data and total area cooled.

The reduction in electrical input energy was then assessed by application of improved SEER to the total cooling load.

7.4 Other HVAC decarbonisation opportunities

7.4.1 Replacement of aged, fixed speed drives with new variable speed drives

An assessment was made of the current total heating and HVAC electrical power within each building based on record information and metering data. An estimated reduction in pumping energy was made by applying an appropriate factor dependent on the anticipated efficiency improvement achieved by installation of high efficiency variable speed drives.

7.4.2 Provision of zone controls to facilitate local temperature and time control

An appropriate factor was applied to the total heating load within each building to assess the reduction achieved by enhanced zone and time controls. The factor was dependent on the level of zone and time controls within the existing installation to arrive.

7.4.3 Provision of foil faced radiant heat reflectors behind radiators

The energy efficiency associated with installing foil faced reflectors behind radiators has been estimated by consulting with manufacturers to understand the % increase in efficiency when using these reflectors. This was then be applied to the rooms that feature radiator heating in the 6 buildings considered.

7.4.4 Thermal insulation improvements to heat distribution infrastructure

To assess improvements to thermal insulation to heat distribution pipework, the total metered space heating load for each building was reduced by an appropriate factor. The factor for heating load reduction was determined for each building by the estimated age and condition of the existing thermal insulation.

Older buildings / systems with extensive damaged or missing thermal insulation are assumed to have a greater benefit from improvements to thermal insulation and so a greater reduction factor applied to the heating load. Conversely, more recently installed heating systems are assumed to realise a lesser benefit from improved thermal insulation and so a smaller factor has been applied to the annual heating load.

7.4.5 Provision of heat meters

Provision of heat meters will not directly reduce the carbon footprint of the buildings however will enable collection of the data required to target and monitor the effectiveness of the interventions that are implemented.

7.4.6 Provision of side-stream filtration

The impact of side stream filtration will not directly contribute to decarbonisation of heat but does play an important part in improving heating system efficiency, reducing pumping power required and ensuring heat exchanger performance is not degraded.

7.4.7 Provision of new or enhanced automatic controls / BMS

Provision of enhanced BMS controls was assess by applying an appropriate factor against the total heating load for each building. The benchmarking factor applied was dependent on the extent and sophistication of the existing BMS controls.

7.5 New LZC technology / renewable energy opportunities

7.5.1 Provision of new PV installations

Provision of PV technology will not directly contribute to the decarbonisation of heating / cooling but does play an important part in increasing the campus electrical capacity. By increasing electrical capacity more electrical adoption of low or zero carbon technologies such as air source or ground source heat pumps can be maximised.

The available and suitable space for PV installation has been assessed for each building, from which an estimated electrical generation has been derived.

7.6 Electrical decarbonisation opportunities

7.6.1 Replacement of fluorescent luminaires with LED technology

Upgrade of light fittings to more efficient technologies will not directly contribute to the decarbonisation of heating / cooling but does play an important part in reducing the campus electrical demand. By reducing electrical demand associated with lighting, more electrical capacity will be made available for adoption of low or zero carbon technologies such as air source or ground source heat pumps. This effect is further enhanced by a reduction cooling load associated with older lighting technologies.

7.6.2 Provision of automatic lighting controls throughout

As with improved efficiency light fittings, provision of enhanced lighting controls will not directly contribute to the decarbonisation of heating / cooling but does play an important part in reducing the campus electrical demand. By reducing electrical demand associated with lighting, more electrical capacity will be made available for adoption of low or zero carbon technologies such as air source or ground source heat pumps. This effect is further enhanced by a reduction cooling load associated lighting.

8. Decarbonisation Intervention Technical Assessment

8.1 Overview

This section of the report analyses the impact of the various decarbonisation interventions and includes a summary table against each building. These tables are intended to provide the summary information on all the options considered and should be the focal point of the report for the purpose of comparing options and impacts.

The decarbonisation measures within the summary tables have been colour coded to indicate which options should be prioritised or are most suitable, and which options should take less priority or are less suitable. This is based on the cost per CO_2 reduction, the overall CO_2 reduction, the ease of implementation, and site wide strategy.

Green	Denotes that the intervention is recommended for implementation.
Amber	Denotes that the intervention may be less suitable for implementation due to one or more factors.
Red	Denotes that the intervention is unsuitable for implementation due to one or more factors.
Grey	Denotes that the intervention has been excluded from the study due to unsuitability.

Table 14 - Key for colour coding

For each intervention the cost has been divided by the total lifetime carbon emission saving for the intervention to gauge the cost efficiency for the total CO_2 reduction. This enables the carbon reduction for each intervention to be directly compared to other interventions that may have a longer or shorter lifespan.

Indicative operational costs have been included in each table to indicate the savings per annum as a result of the reduction in energy demand for each option. Unit rates for Gas and Electric are based on 2022 average where:

- Gas = £0.074/kWh
- Electric = 0.195/kWh

8.2 Davy Building (as a stand-alone building)

This section discusses addressing Davy Building as a stand-alone building. For solutions relating to the wider heat network, fed from Davy Building, refer to 8.3

8.2.1 Current base heating load

Using metered data, and analysing the available record information, the peak heating load to Davy Building alone is approximately 460kW, and the annual heating load is approximately 412,715 kWh/annum.

8.2.2 Anticipated requirements to fully offset fossil fuel usage

To fully offset fossil fuel usage within Davy building a new heat pump installation would be required to provide the full building heating load.

The heat pump installation would serve all space heating and air heating requirements within the building.

Domestic hot water generation within Davy building is already electrically generated and so could remain as local point of use water heaters. However the overall energy demand of domestic hot water of the building could potentially be reduced by utilisation of high temperature electric driven heat pumps, with a higher generation efficiency, provided that the additional storage and distribution losses do not offset this increase in efficiency.

To install a heat pump system to serve Davy building the below actions / considerations are required;

- Heat pumps to be installed, either at roof level or at ground level on a gantry, as described in section 6.2.4 of this report.
    - If mounted on the roof, there are likely enabling works required to enhance the structural loading of the roof, and modify existing roof mounted services to provide sufficient space to accommodate the heat pump installation, including space for acoustic packs / enclosures and associated pipework distribution.
    - If mounting at ground level, a suitable gantry that would accommodate the required heat pump capacity would need to be installed, that would likely be supported from the ground. There is therefore potential for below ground diversion of services, and / or a structural solution developed to overcome buried services. These heat pumps would need to be provided with acoustic packs due to proximity to occupied areas.
- If installing a low temperature heat pump solution, a wholesale replacement of existing heating systems within Davy building including all distribution pipework and heat emitters, to suit the lower operating temperatures.
- If installing a low temperature heat pump solution, air handling units with LTHW heating coils will need to be adapted to ensure heating coil compatibility with low flow temperatures
- Riser sizes to be reviewed with respect to accommodating larger LTHW pipework associated with low flow temperatures
- Pump sets to be replaced to efficient units suited to required flow rate / duty
- Electrical infrastructure upgrades to ensure sufficient capacity to serve heat pump systems
- Space to be identified for thermal stores / buffer vessels – likely to be within the basement plantroom once gas fired heating plant is removed.
- Replacement of entire heating system throughout Davy building will present significant disruption to occupant activities and will require decant of whole floors / areas of the building including temporary accommodation. A phased approach to the refurbishment would likely need to be considered, for which costs are excluded from this study, along with the costs for decanting.
- Consideration of heating supply to other buildings served by Davy gas fired heating plant (notable Babbage and Brunel buildings which are beyond scope of this plan), as per the below options
    - Gas fired plant is retained within Davy to continue serving the district heat network for the buildings that remain connected to the network
    - Gas fired plant within Davy building is replaced with the heat pump installation and the heat network is extended to serve buildings still connected to the network. Note that temperature compatibility issues may arise within other buildings requiring interventions to enable compatibility. Note that this option must be assessed against available space and electrical capacity for heat pump installation
    - Other buildings served by Davy district heat network are provided with alternative heating source – by way of installation of local dedicated heat generating plant, as defined in respective sections of this report.

Davy building could be served by, and feed into, a potential future 5GDH network with the below actions / considerations;

- This option requires centrally generated ambient temperature heat network. Replace the gas-fired heat generating plant in the Davy plantroom with electrically fuelled low carbon heat pump alternative.
- Installation of water-to-water high temperature heat pumps to serve the existing heating system.
- The high temperature heat pumps would provide compatibility with existing pipework, heat emitter and AHU coils. However due to the age of the system, components in some areas of the building would require full intrusive condition surveys of the existing system to identify any age expired sections of pipework that would need to be replaced.
- Option to replace point of use electric water heaters with centralised hot water system served by high temperature heat pump connected to the 5GDH network. This would require installation of a 2-pipe flow and return system throughout the building requiring additional riser space. Whilst installation of this 2-pipe system would be disruptive, the installation will mainly be within corridors with only local disruption within rooms to serve sanitaryware fittings. It is expected that installation of final connection

to sanitaryware could be managed to minimise disruption to academic activities, possibly by adopting out of hours working. However, this benefit would need a detailed load analysis to be undertaken, to ensure that the carbon reduction savings generated by a high temperature heat pump are not offset by the distribution and storage losses associated with a centrally generated hot water system.

8.2.3 Anticipated enabling works

In order to replace the entire heating system to provide compatibility with local air source heat pumps, significant enabling works would be required.

Ideally, the building would be decanted in full to permit a whole building refurbishment, but it is acknowledged that the specialist activities that are undertaken in this building would be very hard to decant to temporary, or even permanent, accommodation elsewhere on campus.

The building would therefore likely need to be decanted in a phased manner by floor or area, to enable removal of existing ceilings and furniture, to access the pipework and heat emitters to have them replaced. As heat emitters will be larger than the existing, some rooms may require replanning and / or some items of furniture replaced or modified in order to coordinate with the new heating system.

Additional riser space would likely be required, which may impact locally on some room layouts throughout the building. This would require occupants and furniture to be decanted from the rooms affected to form additional riser space. Affected rooms will need to be replanned, potentially requiring new furniture and modification of ceiling grids.

In line with the fabric first approach, adoption of heat pump technologies should ideally be accompanied with upgrade of building fabric thermal performance, including improved cladding to external walls, improved roof u-values, replacement or refurbishment of windows and air infiltration reduced by sealing of building fabric. Whilst this is not a prerequisite to be able to install heat pumps to Davy building, it should certainly feature as a recommendation for the near future, to help reduce the building's energy usage and carbon footprint further.

8.3 Davy Building (as Energy Centre)

8.3.1 Current base heating load

As the heating plant for Davy, Link, Smeaton, Marine and The House are located in the basement of Davy building, which feeds into the associated heat network, there is clear logic in treating all of these buildings as one project, with the associated heating plant being replaced.

Using metered data, and analysing the available record information, the total peak heating load into the heat network is approximately 1.7MW.

8.3.2 Anticipated requirements to fully offset fossil fuel usage

In order to fully offset fossil fuel usage associated with the boilers and CHP located in Davy building, then the full heating load of the existing heat network would need to be provided through alternative means such as a heat pump.

All of the observations and comments made in section 8.2.2 stand true, and the implications on other buildings would also need to be considered, depending on the type of heat pump selected (high or low temperature).

In addition to the previously raised considerations, should a low temperature heat pump solution be opted for, then the existing heat network pipework will need to be replaced with a more suitably sized set of pipework.

As an initial capital expenditure, the cost to replace all heating installations, including all pipework, heat exchangers, heat emitters, pumps, district heating pipework etc. for all 5 of the buildings will be significant, and would entail considerable disruption to the buildings and campus. As such, it is not considered achievable as one major capital project.

There is a far greater sense in treating the replacement of the gas fired heating plant with a directly comparable heat pump replacement, that eliminates fossil fuels from the site, whilst still providing a high level of efficiency. This would include installing circa. 1.7MW (thermal) of high temperature electric heat pump units in a location near the Davy boiler room, to simply replace the operation of the existing aged plant. Most of the infrastructure could still remain in situ (subject to more detailed investigations), and cold then be replaced / upgraded in the foreness of time, when other capital projects could facilitate the work.

8.3.3 Summary – Davy Building

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
Additional fabric thermal insulation	Upgrade thermal insulation to roof	Yes	3.759 TCO_2	£343,000	£3,042 / TCO_2 LT	Gas -20,483 kWh Electric 0 kWh	Gas -£1,514 Electric £0	No	No	All rooftop plant to be removed and replaced. Working around live and sensitive laboratories. Potential presence of asbestos.	
Additional fabric thermal insulation	Replace curtain walling system with improved cladding, of a higher thermal performance	Yes	6.083 TCO_2	£5,701,000	£31,241 / TCO_2 LT	Gas -33,149 kWh Electric 0 kWh	Gas -£2,450 Electric £0	No	Yes	Potential presence of asbestos Major disruption Cost benefit poor	Reclad in 1999. Unlikely to yield significant improvements in isolation however should be considered if heat pump technology to be implemented, particularly in the near future when cladding requires replacing.
Provision of secondary / double glazing	Replacement of single glazed units or thermally inefficient double glazing with thermally efficient double glazed window units	Yes	15.092 TCO_2	£805,000	£1,905 / TCO_2 LT	Gas -82,245 kWh Electric 0 kWh	Gas -£6,080 Electric £0	No	No	Potentially major disruption	Single glazed windows mostly replaced with double glazing in 1999. Unlikely to yield significant improvements in isolation however should be considered if heat pump technology to be implemented. Stair cores predominantly single glazed with seized opening mechanisms
Improving airtightness	Refurbishment of window units to replace seals and ensure closing mechanisms operate correctly. Reapplication of sealing around windows and external doors	Yes	1.395 TCO_2	£150,000	£3,677 / TCO_2 LT	Gas -7,595 kWh Electric 0 kWh	Gas -£561 Electric £0	No	No	None	
Remedial works resulting from thermographic survey	Identification of areas requiring remedial works by thermographic survey	Yes	0.979 TCO_2	N/A – cost assessment dependant on survey results	N/A	Gas -5,337 kWh Electric 0 kWh	Gas -£395 Electric £0	No	Unlikely – dependent on remedial works required	Access to external façade due to height of building – extensive scaffolding may be required	
Low temperature air source heat pumps in lead capacity with gas fired plant	Integration of air source heat pumps with the existing gas fired heating plant to cater for majority of base load. Gas fired plant to	Yes	73.715 TCO_2	£2,072,000	£1,406 / TCO_2 LT	Gas -623,078 kWh Electric +279,799 kWh	Gas -£46,062 Electric +£54,641	Yes	Yes (if on roof or ground level enclosure)	Available space for installation is limited within existing building constraints.	Gas fired plant still retained – heating system not fully decarbonised. Opportunity to install electric boilers for peak loads to further reduce carbon emissions.

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
	provide for peak demands only										
Low temperature air source heat pumps replacing gas fired plant	Removal of gas fired heating plant serving Davy building and all other buildings on heat network, and replacement with low temperature air source heat pumps	Yes	140.029 TCO_2	£3,741,000	£1,336 / TCO_2 LT	Gas -1,072,212 kWh Electric +391,226 kWh	Gas -£79,264 Electric +£76,401	Yes	Yes (if on roof or ground level enclosure)	Low grade heat would not provide sufficient heating to all buildings on network, hence cost required to replace all heating systems in all buildings served from Davy. Would need to replace all pipework, coils, heat emitters etc. Major refurbishment, and/or phasing. Available space for installation is limited within existing building constraints. Fabric upgrade works may be required to provide building compatibility with heat pump flow temperatures.	Consideration required of other buildings served by gas fired heating plant on the district heating network. They either all derive heat from heat network, with new air source heat pumps provided in Davy, or they each are provided with local heat pump solutions.
High temperature air source heat pumps replacing gas fired plant	Removal of gas fired heating plant serving Davy building and all other buildings on heat network, and replacement with high temperature air source heat pumps	Yes	123.694 TCO_2	£2,072,000	£838 / TCO_2 LT	Gas -1,072,212 kWh Electric +503,107 kWh	Gas -£79,264 Electric +£98,249	Yes	Yes (if on roof or ground level enclosure)	Available space for installation is limited within existing building constraints.	Consideration required of other buildings served by gas fired heating plant on the district heating network. They either all derive heat from heat network, with new air source heat pumps provided in Davy, or they each are provided with local heat pump solutions.
Domestic hot water from high temperature heat pumps	Installation of centralised domestic hot water system served by high temperature heat pumps	Yes	1.859 TCO_2	£653,000	£17,564 / TCO_2 LT	Gas 0 kWh Electric -12,735 kWh	Gas £0 Electric -£2,487	Potentially – depending on final peak demand and plant sizing calculations	No	Installation of centralised distribution system requiring service zones and riser space. Management of installation to final connections required to minimise disruption.	Davy building domestic hot water is already generated electrically so carbon efficient. High temperature heat pumps will serve to reduce electrical demand associated with domestic hot water generation
Replacement of split DX cooling systems	Replacement of old, poor efficiency DX split systems with modern high efficiency systems on like for like basis	Yes	1.032 TCO_2	£229,000	£27,028 / TCO_2 LT	Gas 0 kWh Electric -7,070 kWh	Gas £0 Electric -£1,381	No	No		
Replacement of fixed speed drives	Replacement of fixed or aged inefficient variable speed drives with high efficiency generation drives	Yes	8.209 TCO_2	£86,000	£1022 / TCO_2 LT	Gas -35,579 kWh Electric -11,508 kWh	Gas -£2,630 Electric -£2,247	No	No	None	

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
Provision of zone controls to heating system	Installation of local room controls to existing heating systems including zone controls and time clocks	Yes	4.570 TCO_2	£259,000	£4,771 / TCO_2 LT	Gas -24,905 kWh Electric 0 kWh	Gas -£1,841 Electric £0	No	No	Upgrades of BMS required for efficient central control Some pipework reconfigurations may be required to effectively zone heating system	
Provision of foil faced heat reflectors behind emitters	Application of foil faced heat reflectors behind heat emitters on perimeter walls	Yes	0.734 TCO_2	£348,000	£18,965 / TCO_2 LT	Gas -4,003 kWh Electric 0 kWh	Gas -£296 Electric £0	No	No	Installation potentially disruptive requiring removal of fixed furniture to access full length of perimeter heating systems	
Thermal insulation improvements to heating infrastructure	Extent of damaged and missing thermal insulation to be assessed and made good / replaced. Old thermal insulation replaced with modern high-performance systems	Yes	2.611 TCO_2	£86,000	£1,464 / TCO_2 LT	Gas -14,262 kWh Electric 0 kWh	Gas -£1,055 Electric £0	No	No	None	
Provision of side stream filtration	Installation of side stream filtration unit to heating system to maintain optimum water quality to maximise system efficiency	Yes	0.653 TCO_2	£60,000	£9,289 / TCO_2 LT	Gas -3,558 kWh Electric 0 kWh	Gas -£263 Electric £0	No	No	None	
Provision of new / enhanced BMS controls	Installation of modern and improved BMS control system to control and monitor building services	Yes	7.369 TCO_2	£749,000	£12,072 / TCO_2 LT	Gas -35,579 kWh Electric -5,754 kWh	Gas -£2,630 Electric -£1,124	No	No	None	
Provision of PV generation	Installation of PV electrical generators to feed into LV network	Yes	0.572 TCO_2	£100,000	£7,771 / TCO_2 LT	Gas 0 kWh Electric -3,914 kWh	Gas £0 Electric -£764	Potentially – dependant on installed capacity	Unlikely	Roof form and existing roof mounted services limit available space for PV installation Potential conflict for roof space with heat pump installation	
Upgrade lighting to high efficiency LED fittings	Replacement of inefficient lighting technologies with new highly efficient LED lighting	Yes	1.799 TCO_2	£709,000	£15,765 / TCO_2 LT	Gas 0 kWh Electric -12,324 kWh	Gas £0 Electric -£2,407	No	No	None	

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
Provision of automatic lighting controls throughout	Installation of automatic lighting controls including automatic switching and daylight dimming	Yes	0.203 TCO_2	£261,000	£144,625 / TCO_2 LT	Gas 0 kWh Electric -1,388 kWh	Gas £0 Electric -£272	No	No	None	

8.4 Link Building

8.4.1 Current base heating load

Using metered data, and analysing the available record information, the peak heating load to Link Building is approximately 72kW, and the annual heating load is approximately 50,348 kWh/annum.

8.4.2 Anticipated requirements to fully offset fossil fuel usage

To fully offset fossil fuel usage within Link building a new heat pump installation would be required to provide the full building heating load. There are two primary options to achieve this;

1. Install heat pumps within Davy building to feed into the heat network, and include Link Building's load on the heat pump selection (refer to section 8.3 for details).
2. Disconnect Link Building from the heat network, and provide a local solution through heat pumps

This section considers Option 2, only, as Option 1 is discussed elsewhere.

The local heat pump installation would serve all space heating and air heating requirements within the building.

Domestic hot water generation within Link building is already electrically generated and so could remain as local point of use water heaters. However the overall energy demand of domestic hot water of the building could potentially be reduced by utilisation of high temperature electric driven heat pumps, with a higher generation efficiency, provided that the additional storage and distribution losses do not offset this increase in efficiency.

To install a heat pump system to serve Link building the below actions / considerations are required:

- Heat pumps to be installed at roof level as a preference – potential enabling works to modify existing building structure to enhance loadings to accommodate additional plant.
- If installing a low temperature heat pump solution;
    - a wholesale replacement of existing heating systems within Link building including all distribution pipework and heat emitters, including AHU and fan coil unit coils, to suit the lower operating temperatures.
    - Riser sizes to be reviewed with respect to accommodating larger LTHW pipework associated with low flow temperatures
- If installing a high temperature heat pump solution, then hydraulic connection onto existing LTHW distribution from the heat network, allowing to take new LTHW pipework from the roof to the basement.
- Pump sets to be replaced to efficient units suited to require flow rate / duty
- Electrical infrastructure upgrades to ensure sufficient capacity to serve heat pump systems
- Space to be identified for thermal stores / buffer vessels – likely to be on the roof of Link Building.
- Replacement of entire heating system throughout Link building will present noticeable disruption to occupant activities and will require decant of whole floors / areas of the building including temporary accommodation. A phased approach to the refurbishment may need to be considered.

Link building could be served by a potential future 5GDH network with the below actions / considerations, and assuming the existing heat network connection is retained;

- Installation of water-to-water high temperature heat pumps to serve the existing heating system in Link.
- High temperature heat pumps would provide compatibility with existing pipework, heat emitter and AHU coils. However due to the age of the system, components in some areas of the building would require full intrusive condition surveys of the existing system to identify any age expired sections of pipework that would need to be replaced.
- Option to replace point of use electric water heaters with centralised hot water system served by high temperature heat pump connected to the 5GDH network. This would require installation of a 2-pipe flow and return system throughout the building requiring additional riser space. Whilst installation of this 2-pipe system would be disruptive, the installation will mainly be within corridors with only local disruption within rooms to serve sanitaryware fittings. It is expected that installation of final connection to sanitaryware could be managed to minimise disruption to academic activities, possibly by adopting out of hours working.

8.4.3 Anticipated enabling works

In order to replace the entire heating system to provide compatibility with local air source heat pumps significant enabling works would be required.

The building would need to be decanted, potentially in a phased manner by floor or area, to enable removal of existing ceilings and furniture to enable removal of pipework systems and heat emitters. As heat emitters are likely to be larger than the existing, some rooms may require replanning and / or some items of furniture replaced or modified in order to coordinate with the new heating system.

Additional riser space would likely be required, which may impact locally on some room layouts throughout the building. This would require of occupants and furniture to be decanted from the rooms affected to form additional riser space. Affected rooms will need to be replanned, potentially requiring new furniture and modification of ceiling grids.

In line with the fabric first approach, adoption of heat pump technologies should be accompanied with upgrade of building fabric thermal performance, including improved cladding to external walls, improved roof u-values, replacement or refurbishment of windows and air infiltration reduced by sealing of building fabric. Whilst this is not a prerequisite to be able to install heat pumps to Link building, it should certainly feature as a recommendation for the near future, to help reduce the building's energy usage and carbon footprint further.

8.4.4 Summary – Link Building

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
Additional fabric thermal insulation	Upgrade thermal insulation to roof	Yes	0.310 TCO_2	£153,000	£16,452 / TCO_2 LT	Gas -1,691 kWh Electric 0 kWh	Gas -£125 Electric £0	No	No	Potential presence of asbestos	
Additional fabric thermal insulation	Replace curtain walling system with improved cladding, of a higher thermal performance	Yes	0.242 TCO_2	£2,356,000	£324,518 / TCO_2 LT	Gas -1,317 kWh Electric 0 kWh	Gas -£97 Electric £0	No	Yes	Potential presence of asbestos Major disruption Likely cost prohibitive	Reclad in 1999. Unlikely to yield significant improvements in isolation however should be considered if heat pump technology to be implemented.
Provision of secondary / double glazing		No									Existing double glazing in good condition.
Improving airtightness	Refurbishment of window units to replace seals and ensure closing mechanisms operate correctly. Reapplication of sealing around windows and external doors	No									Existing double glazing in good condition.
Remedial works resulting from thermographic survey	Identification of areas requiring remedial works by thermographic survey	Yes	0.080 TCO_2	N/A – cost assessment dependant on survey results	N/A	Gas -434 kWh Electric 0 kWh	Gas -£32 Electric £0	No	Unlikely – dependent on remedial works required	Access to external façade due to height of building – extensive scaffolding may be required	
Low temperature air source heat pumps	Disconnection from existing heat network. Installation of new low temperature air source heat pumps to service Link building only. Upgrade to all internal heat emitters and pipework.	Yes	13.930 TCO_2	£603,000	£2,165 / TCO_2 LT	Gas -86,808 kWh Electric +13,914 kWh	Gas -£6,417 Electric +£2,717	Yes	Yes (if on roof or ground level enclosure)	Low grade heat would not provide sufficient heating to building. Would need to replace all pipework, coils, heat emitters etc. Major refurbishment, and/or phasing. Potential risk of roof structure needing enhancements. Fabric upgrade works may be required to provide building compatibility with heat pump flow temperatures	Roof structures to be checked for suitability for plant to sit on roof.
High temperature air source heat pumps.	Disconnection from existing heat network.	Yes	12.608 TCO_2	£430,000	£1,706 / TCO_2 LT	Gas -86,808 kWh	Gas -£6,417	Yes	Yes (if on roof or ground level enclosure)	Available space for installation is limited within existing building constraints.	Easy integration for high temperature heat pumps into the existing heat network connections –

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
	Installation of new high temperature air source heat pumps to service Link building only.					Electric +22,966 kWh	Electric +£4,485			Fabric upgrade works may be required to provide building compatibility with heat pump flow temperatures	minimal impact on internal distribution and coils in building.
Domestic hot water from high temperature heat pumps	Installation of centralised domestic hot water system served by high temperature heat pumps	Yes	0.561 TCO_2	£532,000	£47,416 / TCO_2 LT	Gas 0 kWh Electric -3,843 kWh	Gas £0 Electric -£751	Potentially – depending on final peak demand and plant sizing calculations	No	Installation of centralised distribution system requiring service zones and riser space Management of installation to final connections required to minimise disruption	Link building domestic hot water is already generated electrically so carbon efficient. High temperature heat pumps will serve to reduce electrical demand associated with domestic hot water generation
Replacement of split DX cooling systems	Replacement of old, poor efficiency DX split systems with modern high efficiency systems on like for like basis	No									
Replacement of fixed speed drives	Replacement of fixed or aged inefficient variable speed drives with high efficiency generation drives	No									
Provision of zone controls to heating system	Installation of local room controls to existing heating systems including zone controls and time clocks	Yes	0.319 TCO_2	£86,000	£22,693 / TCO_2 LT	Gas -1,736 kWh Electric 0 kWh	Gas -£128 Electric £0	No	No	Upgrades of BMS required for efficient central control. Some pipework reconfiguration may be required to effectively zone heating system	
Provision of foil faced heat reflectors behind emitters	Application of foil faced heat reflectors behind heat emitters on perimeter walls	Yes	0.090 TCO_2	£82,000	£36,445 / TCO_2 LT	Gas -488 kWh Electric 0 kWh	Gas -£36 Electric £0	No	No	Installation potentially disruptive requiring removal of fixed furniture to access full length of perimeter heating systems.	
Thermal insulation improvements to heating infrastructure	Extent of damaged and missing thermal insulation to be assessed and made good / replaced. Old thermal insulation replaced with modern high-performance systems	Yes	0.319 TCO_2	£21,000	£2,926 / TCO_2 LT	Gas -1,736 kWh Electric 0 kWh	Gas -£128 Electric £0	No	No	None	Extent and condition of pipework insulation unknown. Would require intrusive surveys to validate.

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
Provision of side stream filtration	Installation of side stream filtration unit to heating system to maintain optimum water quality to maximise system efficiency	Yes	0.080 TCO_2	£60,000	£75,000 / TCO_2 LT	Gas -434 kWh Electric 0 kWh	Gas -£32 Electric £0	No	No	None	
Provision of new / enhanced BMS controls	Installation of modern and improved BMS control system to control and monitor building services	Yes	0.904 TCO_2	£177,000	£26,254 / TCO_2 LT	Gas -4,340 kWh Electric -737 kWh	Gas -£321 Electric -£144	No	No	None	
Provision of PV generation	Installation of PV electrical generators to feed into LV network	Yes	0.970 TCO_2	£163,000	£7,469 / TCO_2 LT	Gas 0 kWh Electric -6,642 kWh	Gas £0 Electric -£1,297	Potentially – dependant on installed capacity	Unlikely	Roof form and existing roof mounted services limit available space for PV installation Potential conflict for roof space with heat pump installation	
Upgrade lighting to high efficiency LED fittings	Replacement of inefficient lighting technologies with new highly efficient LED lighting	Yes	0.744 TCO_2	£293,000	£15,753 / TCO_2 LT	Gas 0 kWh Electric -5,098 kWh	Gas £0 Electric -£995	No	No	None	
Provision of automatic lighting controls throughout	Installation of automatic lighting controls including automatic switching and daylight dimming	Yes	0.203 TCO_2	£62,000	£34,356 / TCO_2 LT	Gas 0 kWh Electric -1,388 kWh	Gas £0 Electric -£271	No	No	None	None

8.5 Smeaton Building

Using metered data, and analysing the available record information, the peak heating load to Smeaton Building is approximately 136kW, and the annual heating load is approximately 84,283 kWh/annum.

8.5.1 Anticipated requirements to fully offset fossil fuel usage

To fully offset fossil fuel usage within Smeaton building a new heat pump installation would be required to provide the full building heating load. There are two primary options to achieve this;

1. Install heat pumps within Davy building to feed into the heat network, and include Smeaton Building's load on the heat pump selection (refer to section 8.3 for details).
2. Disconnect Smeaton Building from the heat network, and provide a local solution through heat pumps

This section considers Option 2, only, as Option 1 is discussed elsewhere.

The local heat pump installation would serve all space heating and air heating requirements within the building.

Domestic hot water generation within Smeaton building is already electrically generated and so could remain as local point of use water heaters. However the overall energy demand of domestic hot water of the building could potentially be reduced by utilisation of high temperature electric driven heat pumps, with a higher generation efficiency, provided that the additional storage and distribution losses do not offset this increase in efficiency.

To install a heat pump system to serve Smeaton building the below actions / considerations are required:

- Heat pumps to be installed at roof level as a preference – potential enabling works to modify existing building form and roof mounted services to provide sufficient space to accommodate the heat pumps, including space for acoustic packs / enclosures and pipework distribution
- If installing a low temperature heat pump solution;
    - a wholesale replacement of existing heating systems within Smeaton building including all distribution pipework and heat emitters, including AHU and fan coil unit coils, to suit the lower operating temperatures.
    - Riser sizes to be reviewed with respect to accommodating larger LTHW pipework associated with low flow temperatures
- If installing a high temperature heat pump solution, then hydraulic connection onto existing LTHW distribution from the heat network, allowing to take new LTHW pipework from the roof to the basement.
- Pump sets to be replaced to efficient units suited to require flow rate / duty
- Electrical infrastructure upgrades to ensure sufficient capacity to serve heat pump systems
- Space to be identified for thermal stores / buffer vessels – likely to be within the Smeaton ground floor plantroom.
- Replacement of entire heating system throughout Smeaton building will present significant disruption to occupant activities and will require decant of whole floors / areas of the building including temporary accommodation. A phased approach to the refurbishment may need to be considered.

Smeaton building could be served by a potential future 5GDH network with the below actions / considerations

- This option requires centrally generated ambient temperature heat network.
- Installation of water-to-water high temperature heat pumps to serve the existing heating system.
- The high temperature heat pumps would provide compatibility with existing pipework, heat emitter and AHU coils. However, due to the age of the system components in some areas of the building require full condition surveys of the existing system to be undertaken to identify any age expired sections of pipework to be removed.
- Option to replace point of use electric water heaters with centralised hot water system served by high temperature heat pump connected to the 5GDH network. This would require installation of a 2-pipe flow and return system throughout the building requiring additional riser space. Whilst installation of this 2-pipe system would be disruptive, the installation will mainly be within corridors with only local disruption within rooms to serve sanitaryware fittings. It is expected that installation of final connection to sanitaryware could be managed to minimise disruption to academic activities, possibly by adopting out of hours working.

8.5.2 Anticipated enabling works

In order to replace the entire heating system to provide compatibility with local air source heat pumps significant enabling works would be required.

The building would need to be decanted, potentially in a phased manner by floor or area, to enable removal of existing ceilings and furniture to enable removal of pipework systems and heat emitters. As heat emitters are likely to be larger than the existing, some rooms may require replanning and / or some items of furniture replaced or modified in order to coordinate with the new heating system.

Additional riser space would likely be required, which may impact locally on some room layouts throughout the building. This would require of occupants and furniture to be decanted from the rooms affected to form additional riser space. Affected rooms will need to be replanned, potentially requiring new furniture and modification of ceiling grids.

In line with the fabric first approach, adoption of heat pump technologies should be accompanied with upgrade of building fabric thermal performance, including improved cladding to external walls, improved roof u-values, replacement or refurbishment of windows and air infiltration reduced by sealing of building fabric.

8.5.3 Summary – Smeaton Building

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
Additional fabric thermal insulation	Upgrade thermal insulation to roof	Yes	1.423 TCO_2	£359,000	£8,410 / TCO_2 LT	Gas -7,754 kWh Electric 0 kWh	Gas -£574 Electric £0	No	No	Potential presence of asbestos	
Additional fabric thermal insulation	Replace curtain walling system with improved cladding, of a higher thermal performance	Yes	1.313 TCO_2	£348,100	£8,838 / TCO_2 LT	Gas -7,155 kWh Electric 0 kWh	Gas -£529 Electric £0	No	Yes	Potential presence of asbestos Major disruption Likely cost prohibitive	Reclad in 1999. Unlikely to yield significant improvements in isolation however should be considered if heat pump technology to be implemented.
Remedial works resulting from thermographic survey	Identification of areas requiring remedial works by thermographic survey	Yes	0.200 TCO_2	N/A – cost assessment dependant on survey results	N/A	Gas -1,090 kWh Electric 0 kWh	Gas -£81 Electric £0	No	Unlikely – dependent on remedial works required	Access to external façade due to height of building – extensive scaffolding may be required	
Provision of secondary / double glazing	Replacement of single glazed units or thermally inefficient double glazing with thermally efficient double glazed window units	Yes	2.191 TCO_2	£553,000	£9,015 / TCO_2 LT	Gas -11,941 kWh Electric 0 kWh	Gas -£883 Electric £0	No	No	Potentially major disruption	Single glazed windows mostly replaced with double glazing in 1999. Unlikely to yield significant improvements in isolation however should be considered if heat pump technology to be implemented. Stair cores predominantly single glazed with seized opening mechanisms
Improving airtightness	Refurbishment of window units to replace seals and ensure closing mechanisms operate correctly. Reapplication of sealing around window units and external doors	Yes	0.440 TCO_2	£111,000	£8,625 / TCO_2 LT	Gas -2,400 kWh Electric 0 kWh	Gas -£177 Electric £0	No	No	None	
Low temperature air source heat pumps	Disconnection from existing heat network. Installation of new low temperature air source heat pumps to service Smeaton building only. Upgrade to all internal heat	Yes	23.301 TCO_2	£758,000	£1,627 / TCO_2 LT	Gas -145,317 kWh Electric +23,412 kWh	Gas -£10,743 Electric +£4,572	Yes	Yes (if on roof or ground level enclosure)	Low grade heat would not provide sufficient heating to building. Would need to replace all pipework, coils, heat emitters etc. Major refurbishment, and/or phasing. Potential risk of roof structure needing enhancements. Fabric upgrade works may be required to provide building	Roof structures to be checked for suitability for plant to sit on roof.

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
	emitters and pipework.									compatibility with heat pump flow temperatures	
High temperature air source heat pumps.	Disconnection from existing heat network. Installation of new high temperature air source heat pumps to service Smeaton building only.	Yes	21.075 TCO_2	£443,000	£1,052 / TCO_2 LT	Gas -145,317 kWh Electric +38,662 kWh	Gas -£10,743 Electric +£7,550	Yes	Yes (if on roof or ground level enclosure)		Easy integration for high temperature heat pumps into the existing heat network connections – minimal impact on internal distribution and coils in building.
Domestic hot water from high temperature heat pumps	Installation of centralised domestic hot water system served by high temperature heat pumps	Yes	1.545 TCO_2	£513,000	£16,602 / TCO_2 LT	Gas 0 kWh Electric -10,581 kWh	Gas £0 Electric -£2,066	Potentially – depending on final peak demand and plant sizing calculations	No	Installation of centralised distribution system requiring service zones and riser space Management of installation to final connections required to minimise disruption	Smeaton building domestic hot water is already generated electrically so carbon efficient. High temperature heat pumps will serve to reduce electrical demand associated with domestic hot water generation
Replacement of split DX cooling systems	Replacement of old, poor efficiency DX split systems with modern high efficiency systems on like for like basis	No									
Replacement of fixed speed drives	Replacement of fixed or aged inefficient variable speed drives with high efficiency generation drives	No									
Provision of zone controls to heating system	Installation of local room controls to existing heating systems including zone controls and time clocks	Yes	0.533 TCO_2	£86,000	£13,582 / TCO_2 LT	Gas -2,906 kWh Electric 0 kWh	Gas -£215 Electric £0	No	No	Upgrades of BMS required for efficient central control Some pipework reconfiguration may be required to effectively zone heating system	
Provision of foil faced heat reflectors behind emitters	Application of foil faced heat reflectors behind heat emitters on perimeter walls	Yes	0.180 TCO_2	£181,000	£40,223 / TCO_2 LT	Gas -981 kWh Electric 0 kWh	Gas -£73 Electric £0	No	No	Installation potentially disruptive requiring removal of fixed furniture to access full length of perimeter heating systems	
Thermal insulation improvements to	Extent of damaged and missing thermal insulation	Yes	0.533 TCO_2	£45,000	£3,753 / TCO_2 LT	Gas -2,906kWh	Gas -£215	No	No	None	

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
heating infrastructure	to be assessed and made good / replaced. Old thermal insulation replaced with modern high-performance systems					Electric 0 kWh	Electric £0				
Provision of side stream filtration	Installation of side stream filtration unit to heating system to maintain optimum water quality to maximise system efficiency	Yes	0.133 TCO_2	£60,000	£45,113 / TCO_2 LT	Gas -727 kWh Electric 0 kWh	Gas -£54 Electric £0	No	No	None	
Provision of new / enhanced BMS controls	Installation of modern and improved BMS control system to control and monitor building services	Yes	1.621 TCO_2	£389,000	£28,501 / TCO_2 LT	Gas -7,266 kWh Electric -1,973 kWh	Gas -£537 Electric -£385	No	No	None	
Provision of PV generation	Installation of PV electrical generators to feed into LV network	Yes	1.869 TCO_2	£307,000	£7,301 / TCO_2 LT	Gas 0 kWh Electric -12,798 kWh	Gas £0 Electric -£2,499	Potentially – dependant on installed capacity	Unlikely	Roof form and existing roof mounted services limit available space for PV installation Potential conflict for roof space with heat pump installation	
Upgrade lighting to high efficiency LED fittings	Replacement of inefficient lighting technologies with new highly efficient LED lighting	Yes	0.298 TCO_2	£118,000	£15,839 / TCO_2 LT	Gas 0 kWh Electric -2,044 kWh	Gas £0 Electric -£399	No	No	None	
Provision of automatic lighting controls throughout	Installation of automatic lighting controls including automatic switching and daylight dimming	Yes	0.152 TCO_2	£136,000	£100,646 / TCO_2 LT	Gas 0 kWh Electric -1,038 kWh	Gas £0 Electric -£203	No	No	None	None

8.7 Scott Building

Using metered data, and analysing the available record information, the peak heating load to Scott Building is approximately 431kW, and the annual heating load is approximately 218,638 kWh/annum.

8.7.1 Anticipated requirements to fully offset fossil fuel usage

To fully offset fossil fuel usage within Scott building a new heat pump installation would be required to provide the full building heating load.

The heat pump installation would serve all space heating and air heating requirements within the building.

Domestic hot water generation within Scott building is already electrically generated and so could remain as local point of use water heaters, however overall energy demand of domestic hot water of the building could be reduced by utilisation of high temperature electric driven heat pumps, with a higher generation efficiency, provided that the additional storage and distribution losses do not offset this increase in efficiency.

To install a heat pump system to serve Scott building the below actions / considerations are required:

- Heat pumps to be installed externally within a dedicated compound, likely in the car park at the front of the building. Heat pumps to include attenuation packs due to proximity to teaching spaces.
- If installing a low temperature heat pump solution;
    - a wholesale replacement of existing heating systems within Scott building including all distribution pipework and heat emitters, including AHU and fan coil unit coils, to suit the lower operating temperatures.
    - Riser sizes to be reviewed with respect to accommodating larger LTHW pipework associated with low flow temperatures
- If installing a high temperature heat pump solution, then hydraulic connection onto existing LTHW distribution from the heat network, allowing to take new LTHW pipework from the roof to the basement.
- Pump sets to be replaced to efficient units suited to require flow rate / duty
- Electrical infrastructure upgrades to ensure sufficient capacity to serve heat pump systems
- Space to be identified for thermal stores / buffer vessels – likely to be within the Scott basement level plantroom.
- Replacement of entire heating system throughout Scott building will present significant disruption to occupant activities and will require decant of whole floors / areas of the building including temporary accommodation. A phased approach to the refurbishment may need to be considered.
- Opportunity for the Scott building to connect to the existing university heat network, fed by the Davy plantroom. This would require decarbonisation of the heat network described in section 8.3, and a review of the existing heat network pipe sizes to accommodate this additional load. Dependant on the operating temperature of the heat network, the existing heat emitters and pipes etc. within Scott would potentially require upgrading throughout if operating temperatures were reduced.

Scott building could be served by a potential future 5GDH network with the below actions / considerations

- This option requires connecting Scott building to a centrally generated ambient temperature heat network.
- Removal of gas-fired heat generators within the plantroom
- Installation of water-to-water high temperature heat pumps to serve the existing heating system.
- The high temperature heat pumps would provide compatibility with existing pipework, heat emitter and AHU coils. However, due to the age of the system components in some areas of the building require full condition surveys of the existing system to be undertaken to identify any age expired sections of pipework to be removed.
- Option to replace point of use electric water heaters with centralised hot water system served by high temperature heat pump connected to the 5GDH network. This would require installation of a 2-pipe flow and return system throughout the building requiring additional riser space. Whilst installation of this 2-pipe system would be disruptive, the installation will mainly be within corridors with only local disruption within rooms to serve sanitaryware fittings. It is expected that installation of final connection to sanitaryware could be managed to minimise disruption to academic activities, possibly by adopting out of hours working.

8.7.2 Anticipated enabling works

In order to replace the entire heating system to provide compatibility with local air source heat pumps significant enabling works would be required.

The building would need to be decanted, potentially in a phased manner by floor or area, to enable removal of existing ceilings and furniture to enable removal of pipework systems and heat emitters. As heat emitters are likely to be larger than the existing, some rooms may require replanning and / or some items of furniture replaced or modified in order to coordinate with the new heating system.

Additional riser space would likely be required, which may impact locally on some room layouts throughout the building. This would require of occupants and furniture to be decanted from the rooms affected to form additional riser space. Affected rooms will need to be replanned, potentially requiring new furniture and modification of ceiling grids.

In line with the fabric first approach, adoption of heat pump technologies should be accompanied with upgrade of building fabric thermal performance, including improved cladding to external walls, improved roof u-values, replacement or refurbishment of windows and air infiltration reduced by sealing of building fabric.

8.7.3 Summary – Scott Building

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
Additional fabric thermal insulation	Upgrade thermal insulation to roof	Yes	4.783 TCO_2	£330,000	£2,300 / TCO_2 LT	Gas -26,068 kWh Electric 0 kWh	Gas -£1,927 Electric £0	No	No	Potential presence of asbestos	
Additional fabric thermal insulation	Install internal insulation with improved thermal performance	Yes	17.044 TCO_2	£2,551,000	£4,990 / TCO_2 LT	Gas -92,881 kWh Electric 0 kWh	Gas -£6,866 Electric £0	No	Yes	Potential presence of asbestos Major disruption Practicalities of adding significant levels of internal insulation are difficult, as to achieve noticeable thermal improvements on the existing wall makeup, an air gap and insulation will need to be provided, eating into the GIA of the building.	Historical building unlikely to be externally clad, therefore recommend internal insulation.
Provision of secondary / double glazing	Replacement of single glazed sash windows or thermally inefficient secondary glazing with thermally efficient double glazed window units	Yes	2.929 TCO_2	£857,000	£10,450 / TCO_2 LT	Gas -15,960 kWh Electric 0 kWh	Gas -£1,180 Electric £0	No	No	Potentially major disruption Could affect the external appearance of building, which may become a Planning consideration.	Installing double / secondary glazing should yield significant savings. Double glazed windows to be aesthetically similar to existing.
Improving airtightness	Refurbishment of window units to replace seals and ensure closing mechanisms operate correctly. Reapplication of sealing around window units and external doors	Yes	0.356 TCO_2	£57,000	£5,474 / TCO_2 LT	Gas -1,941 kWh Electric 0 kWh	Gas -£143 Electric £0	No	No	None	Due to the condition of existing windows this may yield significant energy savings.
Remedial works resulting from thermographic survey	Identification of areas requiring remedial works by thermographic survey	Yes	0.446 TCO_2	N/A – cost assessment dependant on survey results	N/A	Gas -2,429 kWh Electric 0 kWh	Gas -£180 Electric £0	No	Unlikely – dependent on remedial works required	Access to external façade due to height of building – extensive scaffolding may be required Being able to fix poor thermal bridging details on old building could be problematic.	
Air source heat pumps in lead capacity with gas fired plant	Integration of air source heat pumps with the existing gas fired heating plant to cater for majority of base load. Gas fired	Yes	17.868 TCO_2	£768,000	£2,150 / TCO_2 LT	Gas -121,466 kWh Electric +30,585 kWh	Gas -£8,979 Electric +£5,973	Yes	Yes (if ground level enclosure)	Available space for installation is limited within existing building constraints. Heat pumps to go in car park.	Gas fired plant still retained – heating system not fully decarbonised

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
	plant to provide for peak demands only										
Low temperature air source heat pumps replacing gas fired plant	Removal of gas fired heating plant serving Scott building and replacement with low temperature air source heat pumps	Yes	35.737 TCO_2	£949,000	£1,328 / TCO_2 LT	Gas -242,931 kWh Electric +61,170 kWh	Gas -£17,959 Electric +£11,946	Yes	Yes (if ground level enclosure)	Low grade heat would not provide sufficient heating to building. Would need to replace all pipework, coils, heat emitters etc. Major refurbishment, and/or phasing. Available space for installation is limited within existing building constraints. Fabric upgrade works may be required to provide building compatibility with heat pump flow temperatures New external enclosure for heat pumps could present a risk / complication. Would need to route pipework into the existing boiler room to connect to existing infrastructure,	Consideration required for where to site external units with minimal impact.
High temperature air source heat pumps replacing gas fired plant	Removal of gas fired heating plant serving Scott building and replacement with high temperature air source heat pumps	Yes	29.939 TCO_2	£717,000	£1,198 / TCO_2 LT	Gas -242,931 kWh Electric +100,879 kWh	Gas -£17,959 Electric +£19,700	Yes	Yes (if on roof or ground level enclosure)	New external enclosure for heat pumps could present a risk / complication. Would need to route pipework into the existing boiler room to connect to existing infrastructure,	Consideration required for where to site external units with minimal impact.
Domestic hot water from high temperature heat pumps	Installation of centralised domestic hot water system served by high temperature heat pumps	Yes	1.176 TCO_2	£506,000	£21,514 / TCO_2 LT	Gas 0 kWh Electric -8,057 kWh	Gas £0 Electric +£1,573	Potentially – depending on final peak demand and plant sizing calculations	No	Installation of centralised distribution system requiring service zones and riser space Management of installation to final connections required to minimise disruption	Scott building domestic hot water is already generated electrically so carbon efficient. High temperature heat pumps will serve to reduce electrical demand associated with domestic hot water generation
Replacement of split DX cooling systems	Replacement of old, poor efficiency DX split systems with modern high efficiency systems on like for like basis	No									
Replacement of fixed speed drives	Replacement of fixed or aged inefficient variable speed drives with high efficiency generation drives	No									

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
Provision of zone controls to heating system	Installation of local room controls to existing heating systems including zone controls and time clocks	Yes	0.892 TCO_2	£86,000	£8,116 / TCO_2 LT	Gas -4,859 kWh Electric 0 kWh	Gas -£359 Electric £0	No	No	Upgrades of BMS required for efficient central control Some pipework reconfiguration may be required to effectively zone heating system	
Provision of foil faced heat reflectors behind emitters	Application of foil faced heat reflectors behind heat emitters on perimeter walls	Yes	1.505 TCO_2	£126,000	£3,349 / TCO_2 LT	Gas -8,199 kWh Electric 0 kWh	Gas -£606 Electric £0	No	No	Installation potentially disruptive requiring removal of fixed furniture to access full length of perimeter heating systems	
Thermal insulation improvements to heating infrastructure	Extent of damaged and missing thermal insulation to be assessed and made good / replaced. Old thermal insulation replaced with modern high-performance systems	Yes	0.892 TCO_2	£31,000	£1,545 / TCO_2 LT	Gas -4,859 kWh Electric 0 kWh	Gas -£359 Electric £0	No	No	None	
Provision of side stream filtration	Installation of side stream filtration unit to heating system to maintain optimum water quality to maximise system efficiency	Yes	0.223 TCO_2	£60,000	£26,906 / TCO_2 LT	Gas -1,215 kWh Electric 0 kWh	Gas -£90 Electric £0	No	No	None	
Provision of new / enhanced BMS controls	Installation of modern and improved BMS control system to control and monitor building services	Yes	2.281 TCO_2	£271,000	£14,111/ TCO_2 LT	Gas -12,147 kWh Electric -356 kWh	Gas -£898 Electric -£69	No	No	None	
Provision of PV generation	Installation of PV electrical generators to feed into LV network	Yes	1.198 TCO_2	£200,000	£7,420 / TCO_2 LT	Gas 0 kWh Electric -8,208 kWh	Gas £0 Electric -£1,603	Potentially – dependant on installed capacity	Unlikely	Roof form and existing roof mounted services limit available space for PV installation Potential conflict for roof space with heat pump installation	
Upgrade lighting to high efficiency LED fittings	Replacement of inefficient lighting technologies with new highly efficient LED lighting	Yes	0.847 TCO_2	£334,000	£15,774 / TCO_2 LT	Gas 0 kWh Electric -5,800 kWh	Gas £0 Electric -£1,133				

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
Provision of automatic lighting controls throughout	Installation of automatic lighting controls including automatic switching and daylight dimming	Yes	0.187 TCO_2	£95,000	£57,146 / TCO_2 LT	Gas 0 kWh Electric -1,278 kWh	Gas £0 Electric -£250	No	No	None	None

8.8 Marine Building

Using metered data, and analysing the available record information, the peak heating load to Marine Building is approximately 160kW, and the annual heating load is approximately 47,846 kWh/annum.

8.8.1 Anticipated requirements to fully offset fossil fuel usage

To fully offset fossil fuel usage within Marine Building a new heat pump installation would be required to provide the full building heating load. There are two primary options to achieve this;

1. Install heat pumps within Davy building to feed into the heat network, and include Marine Building's load on the heat pump selection (refer to section 8.3 for details).
2. Disconnect Marine Building from the heat network, and provide a local solution through heat pumps

This section considers Option 2, only, as Option 1 is discussed elsewhere.

The local heat pump installation would serve all space heating and air heating requirements within the building, as well as providing thermal contribution to the existing solar thermal calorifier.

To install a heat pump system to serve Marine building the below actions / considerations are required:

- Heat pumps to be installed either on the roof or the mezzanine deck containing the AHU – potential enabling works to modify existing building structure to enhance loadings to accommodate additional plant.
- If installing a low temperature heat pump solution;
    - a wholesale replacement of existing heating systems within Marine building including all distribution pipework and heat emitters, including AHU coils, to suit the lower operating temperatures.
    - Riser sizes to be reviewed with respect to accommodating larger LTHW pipework associated with low flow temperatures
- If installing a high temperature heat pump solution, then hydraulic connection onto existing LTHW distribution from the heat network, allowing to take new LTHW pipework from the roof to the basement plantroom. Route to be taken through existing west riser. High temperature supply would serve the solar thermal calorifier also (as a secondary source of heating only).
- Electrical infrastructure upgrades to ensure sufficient capacity to serve heat pump systems
- Thermal store to be added into basement plantroom (sufficient space).
- Replacement of entire heating system throughout Marine building will present significant disruption to occupant activities and will require decant of whole floors / areas of the building including temporary accommodation. A phased approach to the refurbishment may need to be considered.

Marine building could be served by a potential future 5GDH network with the below actions / considerations.

- This option requires centrally generated ambient temperature heat network.
- Installation of water-to-water high temperature heat pumps to serve the existing heating system.
- The high temperature heat pumps would provide compatibility with existing pipework, heat emitter and AHU coils.

8.8.2 Anticipated enabling works

In order to replace the entire heating system to provide compatibility with local air source heat pumps significant enabling works would be required.

The building would need to be decanted, potentially in a phased manner by floor or area, to enable removal of existing ceilings and furniture to enable removal of pipework systems and heat emitters. As heat emitters are likely to be larger than the existing, some rooms may require replanning and / or some items of furniture replaced or modified in order to coordinate with the new heating system.

Additional riser space would likely be required, which may impact locally on some room layouts throughout the building. This would require of occupants and furniture to be decanted from the rooms affected to form additional riser space. Affected rooms will need to be replanned, potentially requiring new furniture and modification of ceiling grids.

8.8.3 Summary –Marine Building

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
Additional fabric thermal insulation	Upgrade thermal insulation to roof	No						No	No		Since this is one of the more recent constructions on site this is unlikely to yield significant improvements in isolation however should be considered if heat pump technology to be implemented.
Additional fabric thermal insulation	Replace curtain walling system with improved cladding, of a higher thermal performance	No						No	Yes		As above
Provision of secondary / double glazing	Replacement of single glazed units or thermally inefficient double glazing with thermally efficient double glazed window units	No									Due to age of the building, the existing glazing is of a good standard.
Improving airtightness	Refurbishment of window units to replace seals and ensure closing mechanisms operate correctly. Reapplication of sealing around windows and external doors	No									Due to age of the building, the air permeability is deemed to be reasonable.
Remedial works resulting from thermographic survey	Identification of areas requiring remedial works by thermographic survey	No									Due to age of the building, the building thermal performance is deemed to be reasonable.
Low temperature air source heat pumps	Disconnection from existing heat network. Installation of new low temperature air source heat pumps to service Marine building only. Upgrade to all internal heat	Yes	13.318 TCO_2	£716,000	£2,689 / TCO_2 LT	Gas -82,494 kWh Electric +12,672 kWh	Gas -£6,098 Electric +£2,475	Yes	Yes (if at roof level)	Low grade heat would not provide sufficient heating to building. Would need to replace all pipework, coils, heat emitters etc. Major refurbishment, and/or phasing. Potential risk of roof structure needing enhancements.	Roof structures to be checked for suitability for plant to sit on roof.

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
	emitters and pipework.										
High temperature air source heat pumps.	Disconnection from existing heat network. Installation of new high temperature air source heat pumps to service Marine building only.	Yes	12.094 TCO_2	£457,000	£1,890 / TCO_2 LT	Gas -82,494 kWh Electric +21,056 kWh	Gas -£6,098 Electric +£4,112	Yes	Yes (if on roof or ground level enclosure)		Easy integration for high temperature heat pumps into the existing heat network connections – minimal impact on internal distribution and coils in building. Would provide opportunity to provide efficiently generated heat to solar thermal calorifier as a secondary heat source.
Domestic hot water from high temperature heat pumps	Replace heat network heating source to generate domestic hot water with supply from high temperature heat pump (as secondary supply only)	Yes	4.030 TCO_2	£600,000	£7,445 / TCO_2 LT	Gas -29,778 kWh Electric +9,822 kWh	Gas -£2,202 Electric +£1919	No	No	Hot water usage profiles to be understood, to ensure solar thermal system, is correctly sized.	Optimisation and load profiling of hot water system recommended before intervention occurs. Straight swap of heat network with high temperature heat pumps would benefit, only if heat network remains gas fired.
Replacement of split DX cooling systems	Replacement of old, poor efficiency DX split systems with modern high efficiency systems on like for like basis	No									Not applicable
Replacement of fixed speed drives	Replacement of fixed or aged inefficient variable speed drives with high efficiency generation drives	No						No	No	None	All plant provided with VSDs
Provision of zone controls to heating system	Installation of local room controls to existing heating systems including zone controls and time clocks	No						No	No	None	Existing zonal controls very good due to age and design of building.
Provision of foil faced heat reflectors behind emitters	Application of foil faced heat reflectors behind heat emitters on perimeter walls	Yes	0.019 TCO_2	£144,000	£303,158 / TCO_2 LT	Gas -103 kWh Electric 0 kWh	Gas -£8 Electric £0	No	No	Installation potentially disruptive and low value.	
Thermal insulation improvements to	Extent of damaged and missing thermal	No						No	No	None	Due to the age of the building thermal insulation is unlikely to be

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
heating infrastructure	insulation to be assessed and made good / replaced. Old thermal insulation replaced with modern high-performance systems										poor condition in need of replacement. Energy savings made will be minimal.
Provision of side stream filtration	Installation of side stream filtration unit to heating system to maintain optimum water quality to maximise system efficiency	Yes	0.038 TCO_2	£60,000	£157,895 / TCO_2 LT	Gas -206 kWh Electric 0 kWh	Gas -£15 Electric £0	No	No	None	
Provision of new / enhanced BMS controls	Installation of modern and improved BMS control system to control and monitor building services	Yes	0.722 TCO_2	£309,000	£50,829 / TCO_2 LT	Gas -1,650 kWh Electric -2,869 kWh	Gas -£122 Electric -£560	No	No	None	BMS Optimisation programme recommended. Due to age of building, controls system is perfectly adequate.
Provision of PV generation	Installation of PV electrical generators to feed into LV network	Yes	0.831 TCO_2	£141,000	£7,542 / TCO_2 LT	Gas 0 kWh Electric -5,693 kWh	Gas £0 Electric -£1,112	Potentially – dependant on installed capacity	Unlikely	Roof form and existing roof mounted services limit available space for PV installation Potential conflict for roof space with heat pump installation	
Upgrade lighting to high efficiency LED fittings	Replacement of inefficient lighting technologies with new highly efficient LED lighting	Yes	0.531 TCO_2	£209,000	£15,744 / TCO_2 LT	Gas 0 kWh Electric -3,638 kWh	Gas £0 Electric -£711	No	No	None	Majority of light fittings seen to be LEDs. Upgrading the remaining fluorescent light fittings will yield minimal energy savings.
Provision of automatic lighting controls throughout	Installation of automatic lighting controls including automatic switching and daylight dimming	Yes	0.166 TCO_2	£108,000	£73,184 / TCO_2 LT	Gas 0 kWh Electric -1,135 kWh	Gas £0 Electric -£222	No	No	None	None

8.9 The House

Using metered data, and analysing the available record information, the peak heating load to the House is approximately 86kW, and the annual heating load is approximately 26,686 kWh/annum.

8.9.1 Anticipated requirements to fully offset fossil fuel usage

To fully offset fossil fuel usage within The House a new heat pump installation would be required to provide the full building heating load. There are two primary options to achieve this;

1. Install heat pumps within Davy building to feed into the heat network, and include The House's load on the heat pump selection (refer to section 8.3 for details).
2. Disconnect The House from the heat network, and provide a local solution through heat pumps

This section considers Option 2, only, as Option 1 is discussed elsewhere.

The local heat pump installation would serve all space heating and air heating requirements within the building, as well as providing thermal contribution to the existing solar thermal calorifier.

To install a heat pump system to serve The House building the below actions / considerations are required:

- Available location for heat pumps is extremely limited in and around The House, hence any associated heat pumps would need to be located near the Davy boiler room.
- If installing a low temperature heat pump solution;
    - a wholesale replacement of existing heating systems within The House including all distribution pipework and heat emitters, including AHU coils, to suit the lower operating temperatures.
    - Riser sizes to be reviewed with respect to accommodating larger LTHW pipework associated with low flow temperatures
- If installing a high temperature heat pump solution, then hydraulic connection onto existing heat network could be made, to directly feed into The House's circuit.
- Electrical infrastructure upgrades to ensure sufficient capacity to serve heat pump systems
- Thermal store to be added into the system somewhere, preferably as part of the heat pump installation near Davy.
- If low temperature heat pumps are installed, then the replacement of entire heating system throughout The House will present significant disruption to occupant activities and will require decant of whole floors / areas of the building including temporary accommodation. A phased approach to the refurbishment may need to be considered.

The House could be served by a potential future 5GDH network with the below actions / considerations.

- This option requires centrally generated ambient temperature heat network.
- Installation of water-to-water high temperature heat pumps to serve the existing heating system.
- The high temperature heat pumps would provide compatibility with existing pipework, heat emitter and AHU coils.

8.9.2 Anticipated enabling works

In order to replace the entire heating system to provide compatibility with local air source heat pumps significant enabling works would be required.

Works would be required to accommodate heat pumps dedicated to The House, located around Davy boiler room. This would involve siting heat pumps near the Davy boiler room, adding new thermal stores and controls for these dedicated heat pumps, and connecting into the circuit serving the House only.

8.9.3 Summary – The House

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
Additional fabric thermal insulation	Upgrade thermal insulation to roof	No						No	No	All rooftop plant to be removed and replaced.	Since this is one of the more recent constructions on site this is unlikely to yield significant improvements in isolation however should be considered if heat pump technology to be implemented.
Additional fabric thermal insulation	Replace curtain walling system with improved cladding, of a higher thermal performance	No						No	Yes	Major disruption Likely cost prohibitive	As above
Provision of secondary / double glazing	Replacement of single glazed units or thermally inefficient double glazing with thermally efficient double glazed window units	No									
Improving airtightness	Refurbishment of window units to replace seals and ensure closing mechanisms operate correctly. Reapplication of sealing around windows and external doors	No									
Remedial works resulting from thermographic survey	Identification of areas requiring remedial works by thermographic survey	No									Due to age of the building, the building thermal performance is deemed to be reasonable.
Low temperature air source heat pumps	Disconnection from existing heat network. Installation of new low temperature air source heat pumps to service The House only. Upgrade to all internal heat emitters and pipework.	Yes	7.375 TCO_2	£568,000	£3,851 / TCO_2 LT	Gas -46,011 kWh Electric +7,430 kWh	Gas -£3,401 Electric +£1,451	Yes	Yes (if on roof or ground level enclosure)	Low grade heat may provide sufficient heating to building. Would need to replace pipes, coils, and some heat emitters etc. Underfloor heating to remain as installed. Some impact on central ventilation plant and accessing all heating coils in the building.	

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
High temperature air source heat pumps.	Disconnection from existing heat network. Installation of new high temperature air source heat pumps to service The House only.	Yes	6.672 TCO_2	£436,000	£3,268 / TCO_2 LT	Gas -46,011 kWh Electric +12,248 kWh	Gas -£3,401 Electric +£2,392	Yes	Yes (if on roof or ground level enclosure)		Easy integration for high temperature heat pumps into the existing heat network connections – minimal impact on internal distribution and coils in building.
Domestic hot water from high temperature heat pumps	Installation of centralised domestic hot water system served by high temperature heat pumps	No									
Replacement of split DX cooling systems	Replacement of old, poor efficiency DX split systems with modern high efficiency systems on like for like basis	No									
Replacement of fixed speed drives	Replacement of fixed or aged inefficient variable speed drives with high efficiency generation drives	No						No	No	None	All plant provided with VSDs
Provision of zone controls to heating system	Installation of local room controls to existing heating systems including zone controls and time clocks	No						No	No	None	Existing zonal controls very good due to age and design of building.
Provision of foil faced heat reflectors behind emitters	Application of foil faced heat reflectors behind heat emitters on perimeter walls	No						No	No	Installation potentially disruptive requiring removal of fixed furniture to access full length of perimeter heating systems	Majority of spaces heated via underfloor the few radiators installed would yield little benefit from this measure.
Thermal insulation improvements to heating infrastructure	Extent of damaged and missing thermal insulation to be assessed and made good / replaced. Old thermal insulation replaced with modern high-performance systems	No						No	No	None	Due to the age of the building thermal insulation is unlikely to be poor condition in need of replacement. Energy savings made will be minimal.

Decarbonisation measure	Description	Viable?	Estimated Annual Carbon Reduction (TCO_2/annum)	Estimated Cost (£)	Cost per Tonne CO_2e Lifetime (£/TCO_2 LT)	Change in kWh/annum After Intervention (kWh)	Change in Operating cost/annum (£)	Electrical Supply Upgrade Required?	Potential Public Consultations	Key Constraints / Risks	Notes
Provision of side stream filtration	Installation of side stream filtration unit to heating system to maintain optimum water quality to maximise system efficiency	Yes	0.021 TCO_2	£60,000	£285,715 / TCO_2 LT	Gas -115kWh Electric 0 kWh	Gas -£9 Electric £0	No	No	None	
Provision of new / enhanced BMS controls	Installation of modern and improved BMS control system to control and monitor building services	Yes	0.132 TCO_2	£127,000	£114,267 / TCO_2 LT	Gas -593 kWh Electric -156 kWh	Gas -£44 Electric £31	No	No	None	BMS Optimisation programme recommended. Due to age of building, controls system is perfectly adequate.
Provision of PV generation	Installation of PV electrical generators to feed into LV network	Yes	0.693 TCO_2	£11,900	£764 / TCO_2 LT	Gas 0 kWh Electric -4,744 kWh	Gas £0 Electric £926	Potentially – dependant on installed capacity	Unlikely	Structural integrity of roof, and whether sufficient capacity for new PVs to be installed. Access to also be considered.	
Upgrade lighting to high efficiency LED fittings	Replacement of inefficient lighting technologies with new highly efficient LED lighting	No						No	No	None	Majority of light fittings seen to be LEDs. Upgrading the remaining fluorescent light fittings will yield minimal energy savings.
Provision of automatic lighting controls throughout	Installation of automatic lighting controls including automatic switching and daylight dimming	Yes	0.140 TCO_2	£44,000	£35,353 / TCO_2 LT	Gas 0 kWh Electric -960 kWh	Gas £0 Electric £187	No	No	None	None

9. Electrical Loading Capacity

9.1 Overview

For each building, an individual desktop study has been carried out, where the recorded electrical and heat demand figures have been used to predict the new electrical demand. This assumes there are no significant changes to the building usage or heating demands.

The predicted heat pump electrical demand was added to the existing electrical consumption data to determine the new maximum electrical demand for each building. This has been assessed on a building-by-building basis, on the premise that if a single building were to be decarbonised through heat pumps, then the heat pumps would be sized against that building's load profile, and would likely be powered from the building it is serving.

However, there are far greater advantages to installing central heat pumps, and utilising the existing heat network that is present, that is fed from the Davy boiler room. By replacing the gas fired plant in Davy building in its entirety, and installing electrically powered heat sources will have the greatest carbon reduction benefit. In this scenario, the full electrical load of all buildings supported off the heat network (which could/should be extended) will be derived from Davy Building incoming electrical supplies.

The new demand figures will need to be compared with the existing peak demands for each building, or for Davy Building if looking at a central heat source. If the new demand exceeds the current agreement, an application for an increase in supply capacity will need to be submitted. Without sight of the agreed capacities for the buildings in question, and also the wider network around the University, we can only surmise that there will likely be the capacity available, based on the following observations;

1. As is indicated in the below graph, there is a general trend in the University's energy consumption values, whereby year-on-year, the usage is steadily reducing. This will be multi-faceted in terms of reasons, that range from more energy efficient plant and equipment being installed, improved controls and monitoring of spaces, behavioural changes and people being more cognisant of their environment, and of course I the last 2 years, significantly reduced occupancy on site.

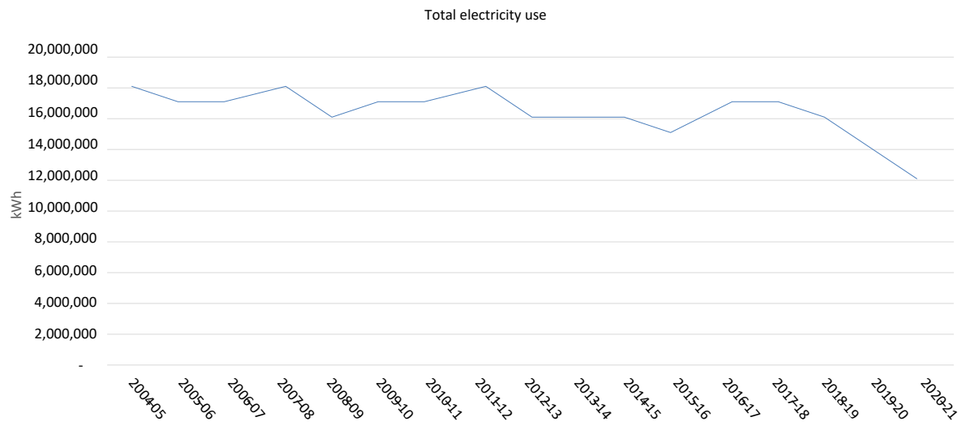


Figure 35 - University of Plymouth Total Energy Use

2. As plant replacements and other carbon reduction measures are getting implemented, the energy consumption will continue to decrease.
3. There is an HV ringmain running around the site – presumably with capacity within it.

9.2 Building Analysis

The following sections identify the impact on the electrical loading capacities should air source heat pumps be implemented for each of the buildings in turn.

9.2.1 Davy Building

On the basis that the new air source heat pumps would serve the thermal load of Davy Building only (i.e. all other buildings fed from the district heating remain so), then the estimated increase in electrical load = 218 kVA for the low temperature and 315kVA for the high temperature solution.

There are sufficient spare ways on the existing main electrical panelboard to accommodate the likely number of new feeds required to power the heat pumps. There are sufficient spare ways on the existing main electrical panelboard to accommodate the likely number of new feeds required to power the heat pumps. The overall load is within the spare capacity entering the building from the susbstation, hence there are no significant infrastructure upgrade works envisaged.

9.2.2 Link Building

On the basis that the new air heat pumps would serve the thermal load of Link Building only (i.e. all other buildings fed from the district heating remain so), then the estimated increase in electrical load = 34 kVA for the low temperature and 50kVA for the high temperature solution.

Although not a large load, this is significant enough to present a potential issue with regards to the incoming mains supply to the Link building, and would necessitate an increase in incoming supply to the building from Davy, as well as a new panelboard.

9.2.3 Smeaton

On the basis that the new air heat pumps would serve the thermal load of the Smeaton Building only, then the estimated increase in electrical load = 65kVA for the low temperature and 94kVA for the high temperature solution.

The current electrical supply into the building and switchgear has limited capacity for future expansion; however, there is a potential for a 160A load when the existing chiller load is utilised, removing the need for switchgear / submains upgrades.

9.2.4 Scott Building

On the basis that the new air heat pumps would serve the thermal load of Scott Building only, then the estimated increase in electrical load = 204kVA for the low temperature and 296kVA for the high temperature solution.

Although not a large load, this is significant enough to present a potential issue with regards to the incoming mains supply to the Scott building and would necessitate an increase in incoming supply, as well as a new switchboard to accommodate the new air heat pumps.

9.2.5 Marine Building

On the basis that the new air heat pumps would serve the thermal load of the Marine Building only, then the estimated increase in electrical load = 76kVA for the low temperature and 150kVA for the high temperature solution.

The current electrical supply into the building and switchgear is capable of supplying the new air heat pumps. There is also an opportunity to utilise the spare capacity from the Marine building to power air heat pumps in adjacent buildings.

9.2.6 The House

On the basis that the new air heat pumps would serve the thermal load of the House Building only, then the estimated increase in electrical load = 42kVA for the low temperature and 59kVA for the high temperature solution.

The current electrical supply into the building and the switchgear is capable of supplying the new air heat pumps.

9.2.7 All buildings combined

If considering the combining of all the buildings under this study (with the exception of Scott) onto a common heat pump solution, that was fed from the existing heat network system from Davy Building, then the total increase in electrical load on Davy Building would equate to approximately 640kVA. This is assuming this is a low temperature heat pump solution.

However, we would anticipate that in order to facilitate the initial decarbonisation of the heating system in a cost-effective manner as possible, that high temperature heat pumps will need to be installed to avoid the huge expense of replacing all pipework and heat emitters in all buildings in a very short period of time. In doing such, the efficiencies of the heat pumps are reduced, and the electrical input will therefore increase to approximately 925kVA.

This increase in load would highly likely necessitate the replacement or significant expansion to the existing main incoming panel board in Davy Building. A board with a larger capacity is unlikely to require a large increase in space compared to the existing unit, and could either be located in the same room, or split and added into the nearby boiler/CHP plantroom (they will become redundant). However, replacing the unit and reinstating the existing installation will require the building to be powered off for a period of time to enable the works to be carried out.

9.2.8 Summary Electrical Loads

Table 15 summarises the electrical loads per building, with the impact of installing local low and high temperature air source heat pumps on the available capacity.

A final line is included which indicates the combined solution, where heat pumps are installed in Davy to replace the gas fired heating plant.

Building	Incoming Supply (kVA)	Peak Demand (kVA)	ASHP Low Temp (LT) Load (kVA)	New Peak Demand (LT) (kVA)	ASHP High Temp (HT) Load (kVA)	New Peak Demand (HT) (kVA)
Davy	800	361	218	579	315	676
Link	From Davy	183	34	217	50	233
Smeaton	277	150	65	215	94	244
Scott	277	122	204	326	296	418
Marine	866	333	76	409	150	483
House	346	187	42	229	59	246
COMBINED	800* (see description)	361	640	1,001	925	1,286

Table 15 - Summary of electrical capacity per building

As can be seen from the above, heat pump solutions applied to Link or Scott in isolation will trigger the requirement for electrical upgrades.

When considering the combined solutions (i.e. air source heat pumps installed to Davy, and all gas fired heating removed), then the increase in electrical loads will exceed the current transformer capacity of 800kVA. However, as can be seen in Figure 36, there is a spare 800kVA transformer off the HV ring, that was disconnected to accommodate the input from the CHP. As this proposed solution will be omitting the CHP, then the existing 800kVA transformer becomes available again, thus increasing available capacity to 1,600kVA. Some modifications will be required to the Davy switchboard, but in principle, powering the air source heat pumps could readily be accommodated within the existing infrastructure.

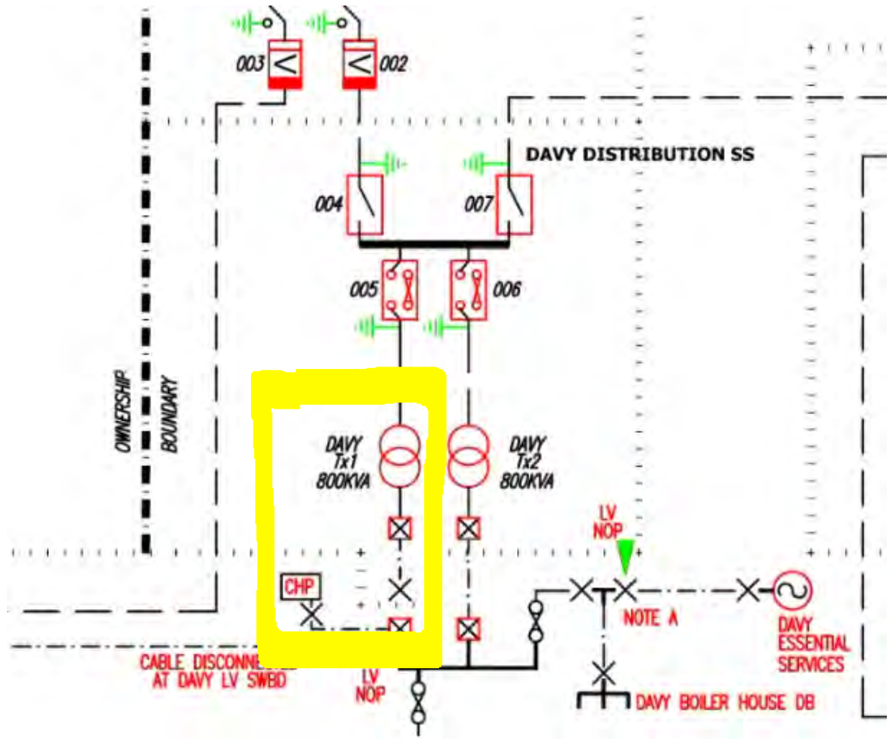


Figure 36 - Excerpt from electrical schematic serving Davy

10. Key Risks

10.1 Overview

As part of the assessment for each building, a high-level assessment has been carried out to identify any key risks associated with identified potential decarbonisation interventions.

10.2 Planning and listed building consent

None of the buildings reviewed are indicated as being Listed, see Figure 37 (courtesy of https://historicengland.org.uk), so there are no immediate concerns in this regard.

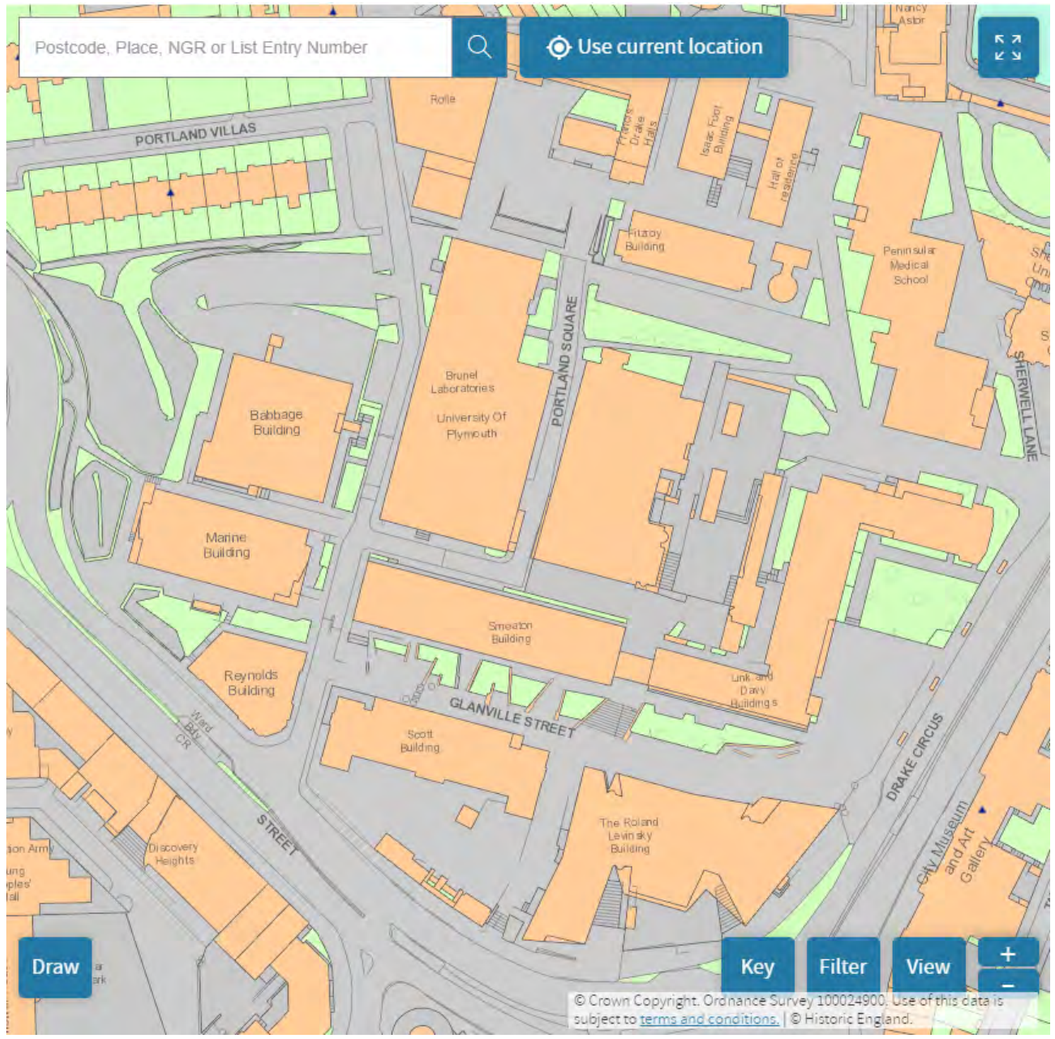


Figure 37 - Historic England map indicating Listed Status of buildings (none noted)

However, Scott Building is of historic importance, and would be subject to consultation with the Planners should any of the works seek to amend the external appearance of the building. This likely would likely attract more rigorous control over any amendments to the external facades.

The same is similar of Davy. Due to its prominent nature, it would likely require consultation with Planners, although it is considered a low risk in the sense that it would simply be a façade replacement measure.

10.3 Asbestos

Due to the variable age of building stock within this plan, including buildings constructed before the ban on asbestos within construction materials, it is likely that some of the buildings will require asbestos removal / control measures to implement some of the interventions.

Davy building is known to contain a significant amount of asbestos, hence the likelihood of this becoming an issue during any intervention works is particularly high. The same is likely true of Link and Smeaton due to their age too.

10.4 Electrical Capacity

University of Plymouth own and operate their private HV main on site, for which there is an agreed maximum capacity of 3,985kVA. Records since Sep 2019 have indicated a maximum demand of no greater than 2,278 kVA, leaving approximately 1,700kVA spare peak demand.

With increased demand on electrical supplies, at some point, we foresee any current headroom being eaten into, and could result in significant electrical infrastructure upgrade works needing to happen, and/or new supplies being brought onto the site to meet the peak loads. Whilst this is unlikely to be realised as part of this project, the culmination of a number of other projects on campus, or new builds etc., could result in this maximum demand exceeding the agreed capacity, hence the University should remain mindful of this.

10.5 Retention of existing heating distribution

Elements of the existing Davy district heating network are considered life expired with unknown condition. Poor condition of pipework and system components can affect system performance, including deterioration of PHEX performance, increase in pumping power and plant reliability issues. The risk associated with retained elements of aged district heating system will increase with time.

11. Next steps and recommendations

This section of the report identifies the recommended interventions and next steps that we consider are appropriate to tackle the University of Plymouth's heat decarbonisation agenda. It should be noted that each of the options previously reviewed have been considered in isolation, so if seeking to incorporate multiple measures, that their compounded effects are considered at further design stages.

11.1 Most cost-efficient interventions

The five most cost-effective individual interventions (£ invested per TCO2 LT reduction) are summarised in Table 16 below.

Intervention	£ per TCO2 LT	Total CO2 reduction per annum
Provision of PV to House	£764 per TCO2 LT	0.693 TCO_2e/annum
High temp ASHP replace gas fired plant to serve heat network	£838 per TCO2 LT	123.694 TCO_2e/annum
Replacement of fixed speed drives to Davy	£1,022 per TCO2 LT	8.209 TCO_2e/annum
Low temp ASHP replace gas fired plant to serve heat network	£1,336 per TCO2 LT	140.029 TCO_2e/annum
Low temp ASHP lead gas fired plant to serve heat network	£1,406 per TCO2 LT	73.715 TCO_2e/annum

Table 16 Top five interventions ranked by cost effectiveness

Whilst replacement of fixed speed drives in Davy and provision of PV to House are more cost-effective measures, the total carbon saved is relatively small in comparison to implementation of ASHPs to serve the heat network.

11.2 Greatest carbon reduction interventions

The five most effective carbon reduction measures are summarised in Table 17 below.

Intervention	Total CO2 reduction	£ per TCO2
Low temp ASHP replace gas fired plant to serve heat network	140.029 TCO_2e/annum	£1,336 per TCO2 LT
High temp ASHP replace gas fired plant to serve heat network	123.694 TCO_2e/annum	£838 per TCO2 LT
Low temp ASHP lead gas fired plant to serve heat network	73.715 TCO_2e/annum	£1,406 per TCO2 LT
Fabric upgrades – walls to Scott building	17.044 TCO_2e/annum	£4,990 per TCO2 LT
Glazing upgrades to Davy building	15.092 TCO_2e/annum	£1,905 per TCO2 LT

Table 17 Top five interventions ranked by total reduction in carbon emissions

11.3 Summary of measures

From the tables above, it can be seen that the most effective measures when considering both total reduction in CO2 and also cost effectiveness are to implement heat pump technologies into the heat network. It therefore follows that **the primary recommendation of this report is to replace all the gas fired heating plant within Davy building with heat pump technologies to serve all associated buildings via the heat network to realise the greatest reduction in carbon emissions**.

Whilst the low temperature heat pump option offers the greatest overall carbon reduction, due to higher SCoP, the cost effectiveness of this option is detrimentally affected by the requirement to modify / replace existing heating systems within all buildings to provide compatibility with lower heating flow temperatures. Implementation of this option therefore presents significant disruption to the buildings affected.

Whilst achieving a lower overall carbon reduction, the high temperature heat pump options will maximise compatibility with the existing heating systems throughout all the buildings affected, minimising extent of system replacement. Therefore, this option becomes more favourable in terms of cost effectiveness. It is therefore **recommended that the gas fired plant serving the district heat network are replaced with high temperature air source heat pumps** to achieve a significant reduction in carbon emissions.

In conjunction with installation of high temperature heat pumps, further significant reductions in carbon emissions can be achieved from implementation of other key interventions. These will act to improve the thermal performance of the building stock to minimise electrical demand. As the primary recommendation of this report is to decarbonise the heat network with heat pump technologies, further recommended interventions have been considered discounting the standalone heat pump options for each building.

Discounting standalone heat pump systems, the most effective interventions (i.e. the greatest carbon reduction in total) are summarised in Table 18 below. It should be noted that whilst these interventions are ranked in terms of total carbon reduction across all buildings, the benefit will be primarily realised from older building stock, as newer building stock is generally includes better performing constructions and building systems. The newer building stock will generally benefit most from provision of PV. Extensive on-site electrical generation will minimise national grid demand associated with an all-electric heating strategy.

Intervention	Total carbon reduction across all buildings
Fabric upgrades – walls	24.682 TCO_2e/annum
Provision of secondary / double glazing	20.212 TCO_2e/annum
Enhanced BMS controls	13.029 TCO_2e/annum
Generation of air source heat pumps to generate domestic hot water	10.590 TCO_2e/annum
Fabric upgrades – roof	10.275 TCO_2e/annum

Table 18 Top five interventions ranked by total carbon reduction from all buildings (local heat pumps excluded)

11.4 Conclusion of recommended interventions

The recommended interventions are summarised below, in what we would consider to be the most appropriate hierarchy;

1. Installation of high temperature air source heat pumps to replace the gas fired plant within Davy building. The air source heat pump installation shall serve the existing heat network, which will be extended to serve Scott building
2. Improve building fabric thermal performance
3. Provision of secondary / double glazing
4. Provision of enhanced / new BMS controls
5. Installation of air source heat pumps to generate domestic hot water
6. Provision of PV to all buildings

11.5 Next Steps

The following section identifies the recommended next steps to progress the decarbonisation agenda.

11.5.1 Optimisation

Carry out further optimisation projects to reduce site demand. We understand this has been undertaken over recent years, but if there are any outstanding buildings or systems, these should be reviewed. Optimisation projects should include;

- BMS optimisation to ensure optimal control of building systems. Existing BMS systems should be reviewed to ensure they are operating effectively and controlling systems in an energy efficient manner. Condition and capability of aged BMS systems should be assessed and where required systems upgraded to modern BMS systems. All sensors and controllers to be validated and replaced or recalibrated where required. Control strategies and settings to be reviewed to ensure appropriate for any changes of building use / patterns of use.
- Review of local / occupant controls of heating, cooling and ventilation. Provision of local automatic controls where appropriate including overrun timers and absence detection, where appropriate.
- Review of temperature set points including deadbands between heating and cooling systems
- Review of ventilation air flow rate settings and time clock settings
- Optimisation / provision of weather compensation on heating systems
- Seasonal commissioning of heating systems
- Occupant / staff training in correct use of building HVAC systems, where applicable
- Review of planned preventative maintenance to ensure systems operate at peak efficiency (replacement of filters, cleaning strainers etc)

11.5.2 Enhanced metering

Enhance metering provisions in line with earlier suggestions, to fully understand thermal and electrical loadings in the buildings in question. Additional metering is to be provided to capture and correlate all building power consumption by end use to enable detailed analysis of building energy profiles / demands.

Estimated cost of the enhanced metering provisions is provided below

- Davy Building - £96,000
- Link Building - £50,000
- Smeaton - £64,500
- Scott Building - £33,000
- Marine Building - £12,000
- The House - £2,000

Enhanced metering data is vital not only to inform further development of adopted decarbonisation interventions but also for assessment and verification of the effectiveness of the interventions following implementation. Therefore, metering coverage and resolution should be maximised to enable detailed assessment of decarbonisation measures. Meter data granularity to be reviewed across all buildings / meters and instantaneous demand data to be collected in addition to kWh energy data.

Ideally a complete calendar year of data will be obtained prior to implementation of recommended decarbonisation measures to establish a recent and accurate baseline against which to verify carbon reductions.

It is recommended that a detailed metering strategy is developed to ensure a complete and accurate data set is obtained which is adequate to inform and validate implementation of decarbonisation interventions. The metering strategy will establish required data granularity and identify additional meter locations required to meter all building loads, including;

- Space heating - via heat metering to individual building / zones / plant
- Domestic hot water – via electric metering to point of use electric water heaters or heat metering to centralised systems
- Space cooling demand – via electric metering to local cooling units
- Ventilation - via electric metering to air handling plant
- Electric load profiles – via additional metering to distribution boards / circuits
- Heat metering to buildings on Davy heat network but outside scope of this study (Babbage & Brunel)
- Electrical metering to buildings served by HV network but outside scope of this study

11.5.3 Measurement and verification of interventions

Establish a measurement and verification plan to ensure that interventions are assessed against complete and accurate data that represent the energy usage of each building. This will serve as a benchmark that the carbon savings of each intervention can be accurately measured against.

11.5.4 Load assessments

11.5.4.1 Hot water

Through additional metering and monitoring of hot water usage in the buildings, compile a comprehensive load assessment of hot water usage, to ascertain whether there are any real time benefits in centralising hot water generation.

The standards to which hot water calculations are undertaken typically produce significantly greater values than systems in-use, hence having real-time and measured values will help understand whether systems are correctly sized against current usage patterns, that could lead onto further decarbonisation measures being identified.

11.5.5 Heat network

Undertake a detailed load analysis on the existing heat network, and develop a concept design to replace the gas fired CHP and boilers within Davy building with an electrically powered heat source (heat pump). This study has assessed the high level feasibility of this, but in order to ensure optimum sizing of plant and distribution a full load assessment should be undertaken over all the connected / planned buildings. There are aspirations for this network to become a 5th Generation District Heating network in the future, hence ensuring that all buildings are designed to be compatible with this are crucial.

The study should explore in detail all related matters around the heat pump installation, including;

1. Planning
2. Acoustics
3. Electrical load
4. Sizing of the pipework/infrastructure
5. Future expansion of the network and associated strategy

Appendix A – Feasibility cost estimate

Feasibility Cost Estimate - Initial Draft for Discussion

Decarbonisation Works

Hoare Lea for University of Plymouth

MARCH 2022

Document History		
Issue		Comment
Rev 0	24/03/2022	Draft for Discussion Issue
Rev P02	25/03/2022	HL reviewed and amended

Author	Nick Hannett BEng (Hons) PGDip MRICS Associate Partner	*Signed*	*NH*	*Job No.*	TBC
Approved	Jonathan Sharp BSc (Hons) FRICS Partner	*Signed*	*JS*	*Issue Ref.*	-
				Date	24/03/2022

UNIVERSITY OF PLYMOUTH DECARBONISATION
INTRODUCTION
DATE : 25 March 2022

1 Introduction

Ward Williams have been engaged via Hoare Lea to carry out an initial costing exercise on the proposed decarbonisation works for the University of Plymouth. The works include various MEP and building fabric upgrades to six existing buildings; Davy Building, Link Building, Smeaton Building, Scott Building, Marine Building and The House.

2 Summary of Costs

Forecast works have been priced individually, with no collective totals on the basis that there is some overlap between the various elements of work, and as such not all items can be carried out. A summary of all costs can be seen within the Summary section, with detailed breakdowns of cost for each building also included later in the report. Due to the level of design information available costs included in the report should be viewed as an order of cost only.

3 Information Used

Costs have been based on the Draft Hoare Lea Heat Decarbonisation Plan 13 March 2022, and subsequent amendments, along with further information on existing building including drawings. We have also held various reviews and discussions with Hoare Lea to discuss and review queries, and to confirm scope.

4 Assumptions & Exclusions

Key assumptions and exclusions are listed as follows;

- We have assumed that all MEPs works will be carried out direct by an MEP contractor appointed on a single stage design and build basis. We have assumed that the fabric enhancement elements will also be carried out direct and as such have not included MEP subcontractors preliminaries and OH&P markups on these works.
- Inflation has been excluded from the estimate i.e. priced at current day, and rates used are current at 1st Quarter 2022
- Professional fees have been included within the estimate at 8% on the works cost
- Client contingency/risk has been included within the estimate at 10% on the works cost and professional fees
- VAT has been included in the estimate at 20% on all costs
- No allowance for removal of asbestos
- No allowance for remedial works resulting from thermographic surveys
- The project will be carried out in normal working hours, Monday to Friday, with no Client required quiet periods.
- No further works have been allowed to buildings not noted, or to any other buildings on the heat network e.g. Brunel, Babbage
- We have assumed a notional allowance for any change to Davy riser sizes from the High Temperature Heat Pumps to replace Heat Network Option
- No allowance for changes to existing metering, or additional meters/sub meters
- No allowance for decant/recant of staff and equipment

- It is also important that we draw your attention to the current situation regarding availability of construction materials and their potential impact on your construction project. Currently (1Q22) there are nationwide material shortages of cement, aggregates, timber, steel, rebar, aluminium, copper and plastics and this is leading not only to meaningful price rises but extended delays to deliveries. Whilst it is anticipated that the current shortages might ease early into this new year this is by no means certain. In addition labour rates increased significantly last year but the industry is steadily recovering its labour capacity. WWA have recently received and witnessed a number of inflated tender returns that reflect the above dynamics. This has been exacerbated not only by a buoyant market but Contractor's concerns around future risks in securing adequate labour and the on-going/future impact of Covid/Brexit on their preliminaries costs and consequent programme impacts, particularly for longer duration projects. The Building Cost Information Service (BCIS) is currently forecasting an increase in tender prices of 21% over the next 5 years. We do not wish to cause unnecessary alarm, however we are in a challenging period in terms of exceptional market volatility and procuring “competitive” tenders. We will continue to asses and anticipate accurate tender price levels, but it is important to appreciate that there is an elevated risk of inflated tender returns and extended programme periods being received during the course of this year and beyond.
- There are no additional allowances in terms of risk / cost or programme currently within the estimate for the COVID19 pandemic. Although restrictions have now eased it is important to note that the ongoing implications on the economy and more specifically on construction projects are currently unknown, and the current situation remains fluid notwithstanding the impact of any further lockdowns or restrictions. You should be aware this remains a risk for the foreseeable future and it is not possible to forecast with any certainty the potential further effect this may have.

UNIVERSITY OF PLYMOUTH DECARBONISATION
SUMMARY OF COSTS
DATE : 25 March 2022

Item	Description	Qty	Unit	Total (£) (ROUNDED)	Comments
1	***Davy Building Summary***				
1.1	- Roof insulation upgrade	1	item	343,000	See detailed breakdown in Section 1
1.2	- Replace curtain walling system	1	item	5,701,000	See detailed breakdown in Section 1
1.3	- Replace single glazed units with double glazing	1	item	805,000	See detailed breakdown in Section 1
1.4	- Refurbishment of existing window units	1	item	150,000	See detailed breakdown in Section 1
1.5	- Remedial works from thermographic survey	1	item	Excluded	See detailed breakdown in Section 1
1.6	- High Temperature Heat Pumps to serve Davy Building only	1	item	717,000	See detailed breakdown in Section 1
1.7	- Low Temperature Heat Pumps to serve Davy Building only	1	item	1,455,000	See detailed breakdown in Section 1
1.8	- Domestic hot water from high temperature heat pumps	1	item	653,000	See detailed breakdown in Section 1
1.9	- Replacement of split DX cooling systems	1	item	229,000	See detailed breakdown in Section 1
1.10	- Replacement of fixed speed drives	1	item	86,000	See detailed breakdown in Section 1
1.11	- Provision of zone controls to heating system	1	item	259,000	See detailed breakdown in Section 1
1.12	- Provision of foil faced heat reflectors behind emitters on perimeter walls	1	item	348,000	See detailed breakdown in Section 1
1.13	- Thermal insulation improvements to heating infrastructure	1	item	86,000	See detailed breakdown in Section 1
1.14	- Provision of side stream filtration	1	item	60,000	See detailed breakdown in Section 1
1.15	- Provision of new/enhanced BMS controls	1	item	749,000	See detailed breakdown in Section 1
1.16	- Provision of PV generation	1	item	100,000	See detailed breakdown in Section 1
1.17	- Upgrade lighting to high efficiency LED fittings	1	item	709,000	See detailed breakdown in Section 1
1.18	- Provision of automatic lighting controls throughout	1	item	261,000	See detailed breakdown in Section 1
1.19	- Provision of surveys	1	item	33,000	See detailed breakdown in Section 1
2	***Link Building Summary***				
2.1	- Roof insulation upgrade	1	item	153,000	See detailed breakdown in Section 2
2.2	- Replace curtain walling system	1	item	2,356,000	See detailed breakdown in Section 2
2.3	- Remedial works from thermographic survey	1	item	Excluded	See detailed breakdown in Section 2
2.4	- High temperature air source heat pumps - disconnect building from heat network	1	item	430,000	See detailed breakdown in Section 2
2.5	- Low temperature air source heat pumps - disconnect building from heat network	1	item	603,000	See detailed breakdown in Section 2
2.6	- Domestic hot water from high temperature heat pumps	1	item	432,000	See detailed breakdown in Section 2
2.7	- Provision of zone controls to heating system	1	item	86,000	See detailed breakdown in Section 2
2.8	- Provision of foil faced heat reflectors behind emitters on perimeter walls	1	item	82,000	See detailed breakdown in Section 2
2.9	- Thermal insulation improvements to heating infrastructure	1	item	21,000	See detailed breakdown in Section 2
2.10	- Provision of side stream filtration	1	item	60,000	See detailed breakdown in Section 2
2.11	- Provision of new/enhanced BMS controls	1	item	177,000	See detailed breakdown in Section 2
2.12	- Provision of PV generation	1	item	163,000	See detailed breakdown in Section 2
2.13	- Upgrade lighting to high efficiency LED fittings	1	item	293,000	See detailed breakdown in Section 2
2.14	- Provision of automatic lighting controls throughout	1	item	62,000	See detailed breakdown in Section 2
2.15	- Provision of surveys	1	item	20,000	See detailed breakdown in Section 2
3	***Smeaton Building Summary***				
3.1	- Roof insulation upgrade	1	item	359,000	See detailed breakdown in Section 3
3.2	- Replace curtain walling system	1	item	3,481,000	See detailed breakdown in Section 3
3.3	- Remedial works from thermographic survey	1	item	Excluded	See detailed breakdown in Section 3
3.4	- Replace single glazed units with double glazing	1	item	553,000	See detailed breakdown in Section 3
3.5	- Refurbishment of existing window units	1	item	111,000	See detailed breakdown in Section 3
3.6	- High temperature air source heat pumps - disconnect building from heat network	1	item	443,000	See detailed breakdown in Section 3
3.7	- Low temperature air source heat pumps - disconnect building from heat network	1	item	758,000	See detailed breakdown in Section 3
3.8	- Domestic hot water from high temperature heat pumps	1	item	513,000	See detailed breakdown in Section 3
3.9	- Provision of zone controls to heating system	1	item	86,000	See detailed breakdown in Section 3
3.10	- Provision of foil faced heat reflectors behind emitters on perimeter walls	1	item	181,000	See detailed breakdown in Section 3
3.11	- Thermal insulation improvements to heating infrastructure	1	item	45,000	See detailed breakdown in Section 3
3.12	- Provision of side stream filtration	1	item	60,000	See detailed breakdown in Section 3
3.13	- Provision of new/enhanced BMS controls	1	item	389,000	See detailed breakdown in Section 3
3.14	- Provision of PV generation	1	item	307,000	See detailed breakdown in Section 3
3.15	- Upgrade lighting to high efficiency LED fittings	1	item	118,000	See detailed breakdown in Section 3
3.16	- Provision of automatic lighting controls throughout	1	item	136,000	See detailed breakdown in Section 3
3.17	- Provision of surveys	1	item	20,000	See detailed breakdown in Section 3
4	***Scott Building Summary***				
4.1	- Roof insulation upgrade	1	item	330,000	See detailed breakdown in Section 4
4.2	- Replace curtain walling system	1	item	2,551,000	See detailed breakdown in Section 4
4.3	- Replace single glazed units with double glazing	1	item	857,000	See detailed breakdown in Section 4
4.4	- Refurbishment of existing window units	1	item	57,000	See detailed breakdown in Section 4
4.5	- Remedial works from thermographic survey	1	item	Excluded	See detailed breakdown in Section 4
4.6	- Low temperature air source heat pumps in lead capacity with gas fired plant	1	item	768,000	See detailed breakdown in Section 4
4.7	- Low Temperature air source heat pumps replacing gas fired plant	1	item	1,000,000	See detailed breakdown in Section 4
4.8	- High Temperature air source heat pumps replacing gas fired plant	1	item	776,000	See detailed breakdown in Section 4
4.9	- Domestic hot water from high temperature heat pumps	1	item	506,000	See detailed breakdown in Section 4
4.10	- Provision of zone controls to heating system	1	item	86,000	See detailed breakdown in Section 4
4.11	- Provision of foil faced heat reflectors behind emitters on perimeter walls	1	item	126,000	See detailed breakdown in Section 4
4.12	- Thermal insulation improvements to heating infrastructure	1	item	31,000	See detailed breakdown in Section 4
4.13	- Provision of side stream filtration	1	item	60,000	See detailed breakdown in Section 4
4.14	- Provision of new/enhanced BMS controls	1	item	271,000	See detailed breakdown in Section 4
4.15	- Provision of PV generation	1	item	200,000	See detailed breakdown in Section 4
4.16	- Upgrade lighting to high efficiency LED fittings	1	item	334,000	See detailed breakdown in Section 4
4.17	- Provision of automatic lighting controls throughout	1	item	95,000	See detailed breakdown in Section 4
4.18	- Provision of surveys	1	item	20,000	See detailed breakdown in Section 4
5	***Marine Building Summary***				
5.1	- High temperature air source heat pumps - disconnect building from heat network	1	item	457,000	See detailed breakdown in Section 5
5.2	- Low temperature air source heat pumps - disconnect building from heat network	1	item	716,000	See detailed breakdown in Section 5
5.3	- Replacement of fixed speed drives	1	item	35,000	See detailed breakdown in Section 5
5.4	- Provision of zone controls to heating system	1	item	86,000	See detailed breakdown in Section 5
5.5	- Provision of foil faced heat reflectors behind emitters on perimeter walls	1	item	144,000	See detailed breakdown in Section 5
5.6	- Provision of side stream filtration	1	item	60,000	See detailed breakdown in Section 5
5.7	- Provision of new/enhanced BMS controls	1	item	309,000	See detailed breakdown in Section 5
5.8	- Provision of PV generation	1	item	141,000	See detailed breakdown in Section 5
5.9	- Upgrade lighting to high efficiency LED fittings	1	item	209,000	See detailed breakdown in Section 5
5.10	- Provision of automatic lighting controls throughout	1	item	108,000	See detailed breakdown in Section 5
6	***The House Summary***				
6.1	- High temperature air source heat pumps - disconnect building from heat network	1	item	436,000	See detailed breakdown in Section 6
6.2	- Low temperature air source heat pumps - disconnect building from heat network	1	item	568,000	See detailed breakdown in Section 6
6.3	- Replacement of fixed speed drives	1	item	35,000	See detailed breakdown in Section 6

UNIVERSITY OF PLYMOUTH DECARBONISATION
SUMMARY OF COSTS
DATE : 25 March 2022

Item	Description	Qty	Unit	Total (£) (ROUNDED)	Comments
6.4	*- Provision of zone controls to heating system*	*1*	*item*	*86,000*	*See detailed breakdown in Section 6*
6.5	*- Provision of foil faced heat reflectors behind emitters on perimeter walls*	*1*	*item*	*59,000*	*See detailed breakdown in Section 6*
6.6	*- Provision of side stream filtration*	*1*	*item*	*60,000*	*See detailed breakdown in Section 6*
6.7	*- Provision of new/enhanced BMS controls*	*1*	*item*	*127,000*	*See detailed breakdown in Section 6*
6.8	*- Provision of PV generation*	*1*	*item*	*119,000*	*See detailed breakdown in Section 6*
6.9	*- Provision of automatic lighting controls throughout*	*1*	*item*	*44,000*	*See detailed breakdown in Section 6*
7	***Heat Network***				
7.1	*- High Temperature ASHP replacing Gas Fired Plant*	*1*	*item*	*2,072,000*	*See detailed breakdown in Section 7*
7.2	*- Low Temperature Heat Pump*	*1*	*item*	*3,741,000*	

Item	Description	Qty	Unit	Rate	Total (£)	Comments
1.1	**Roof insulation upgrade**					
	Remove & dispose of existing roof coverings	1,230	m2	5	6,150	
	Remove and reinstall rooftop plant to affected areas	1	item	50,000	50,000	Allowance only - required scope TBC
	New insulation and roof covering	1,230	m2	150	184,500	
	Subtotal				**240,650**	
	Client Oncosts					
	Professional Fees	8	%		19,252	
	Client Risk/Contingency	10	%		25,990	
	VAT	20	%		57,178	
	Option Total				**343,071**	**Carry to summary**
1.2	**Replace curtain walling system**					
	Remove existing cladding	5,404	m2	60	324,240	Quantity based on HL schedule for Walls plus Glazing (assume replacement of full envelope)
	Access/scaffold to full building	5,404	m2	80	432,320	
	New cladding to full building	5,404	m2	600	3,242,400	Blended rate (solid/glazed)
	Subtotal				**3,998,960**	
	Client Oncosts					
	Professional Fees	8	%		319,917	
	Client Risk/Contingency	10	%		431,888	
	VAT	20	%		950,153	
	Option Total				**5,700,917**	**Carry to summary**
1.3	**Replace single glazed units with double glazing**					
	Remove existing glazing	672	m2	60	40,320	Stairwells only
	Access/scaffold to affected areas	672	m2	80	53,760	
	New double glazed units	672	m2	700	470,400	
	Subtotal				**564,480**	
	Client Oncosts					
	Professional Fees	8	%		45,158	
	Client Risk/Contingency	10	%		60,964	
	VAT	20	%		134,120	
	Option Total				**804,723**	**Carry to summary**
1.4	**Refurbishment of existing window units**					
	Remedial works to existing windows; adjusting frames and seals, minor repairs, cracked panes, ironmongery adjustment, making good - cost per window	420	nr	250	105,000	
	Subtotal				**105,000**	
	Client Oncosts					
	Professional Fees	8	%		8,400	
	Client Risk/Contingency	10	%		11,340	
	VAT	20	%		24,948	
	Option Total				**149,688**	**Carry to summary**
1.5	**Remedial works from thermographic survey**					
	Unable to price at this stage due to lack of detail on required works				Excluded	
1.6	**High Temperature Heat Pumps to serve Davy Building only**					
	Air source heat pump; 138kW	4	nr	47,000	188,000	Assumes High Temperature load from HL Schedule, 4nr pumps at 30% of load capacity, totalling 120% of load
	Primary heating water circulation pumps	1	item	10,000	10,000	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	12,000	12,000	
	Pressurization unit and expansion vessel	1	nr	5,000	5,000	
	Dosing pot	1	item	1,000	1,000	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Assumes connection to existing main distribution pipework, and sundry modifications
	Plate heat exchanger	1	item	10,000	10,000	
	LV switchboard including new cabling etc	1	item	20,000	20,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		12,450	
	Testing & Commissioning	5	%		21,373	
	Subcontractor Preliminaries	12	%		53,859	
	Subtotal				**502,681**	
	Client Oncosts					
	Professional Fees	8	%		40,214	
	Client Risk/Contingency	10	%		54,290	
	VAT	20	%		119,437	
	Option Total				**716,622**	**Carry to summary**

Item	Description	Qty	Unit	Rate	Total (£)	Comments
1.7	**Low Temperature Heat Pumps to serve Davy Building only**					
	Removal of existing heat source, all distribution pipework, and emitters	1	item	25,000	25,000	
	Replacement of heat emitters and pipework	1	item	302,400	302,400	
	Air source heat pump; 138kW	4	nr	47,000	188,000	Assumes Low Temperature load from HL Schedule, 4nr pumps at 30% of load capacity, totalling 120% of load
	Primary heating water circulation pumps	1	item	10,000	10,000	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	12,000	12,000	
	Pressurization unit and expansion vessel	1	nr	5,000	5,000	
	Dosing pot	1	item	1,000	1,000	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Connection to new main distribution pipework above
	Plate heat exchanger	1	item	10,000	10,000	
	LV switchboard, including new cabling	1	item	20,000	20,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	Allowance for changes to riser sizes to accommodate new systems	1	item	100,000	100,000	Requirement TBC, allowance only
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		25,272	
	Testing & Commissioning	5	%		43,384	
	Subcontractor Preliminaries	12	%		109,327	
	Subtotal				**1,020,382**	
	Client Oncosts					
	Professional Fees	8	%		81,631	
	Client Risk/Contingency	10	%		110,201	
	VAT	20	%		242,443	
	Option Total				**1,454,657**	**Carry to summary**
1.8	**Domestic hot water from high temperature heat pumps**					
	Air source heat pump; 98kW	1	nr	40,000	40,000	
	Primary heating water circulation pumps	1	item	10,000	10,000	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	12,000	12,000	
	Pressurization unit and expansion vessel	1	nr	5,000	5,000	
	Dosing pot	1	item	1,000	1,000	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Connection to new domestic hot water distribution pipework
	Plate heat exchanger	1	item	10,000	10,000	
	LV switchboard including new cabling etc	1	item	20,000	20,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	Removal of existing domestic hot water system	10,086	m2	1	10,086	
	Installation of domestic hot water system	10,086	m2	10	100,860	
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		11,338	
	Testing & Commissioning	5	%		19,464	
	Subcontractor Preliminaries	12	%		49,050	
	Subtotal				**457,798**	
	Client Oncosts					
	Professional Fees	8	%		36,624	
	Client Risk/Contingency	10	%		49,442	
	VAT	20	%		108,773	
	Option Total				**652,637**	**Carry to summary**
1.9	**Replacement of split DX cooling systems**					
	Remove existing DX units, assumed quantity	25	nr	300	7,500	
	New 4kW DX units	25	nr	5,000	125,000	
	BWIC with MEP Services	3	%		3,975	
	Testing & Commissioning	5	%		6,824	
	Subcontractor Preliminaries	12	%		17,196	
	Subtotal				**160,495**	
	Client Oncosts					
	Professional Fees	8	%		12,840	
	Client Risk/Contingency	10	%		17,333	
	VAT	20	%		38,134	
	Option Total				**228,801**	**Carry to summary**
1.10	**Replacement of fixed speed drives**					
	Removal of existing variable speed drives, and replace with new high efficiency generation drives	1	item	50,000	50,000	No detail, allowance per building
	BWIC with MEP Services	3	%		1,500	
	Testing & Commissioning	5	%		2,575	
	Subcontractor Preliminaries	12	%		6,489	

Item	Description	Qty	Unit	Rate	Total (£)	Comments
	Subtotal				**60,564**	
	Client Oncosts					
	Professional Fees	8	%		4,845	
	Client Risk/Contingency	10	%		6,541	
	VAT	20	%		14,390	
	Option Total				**86,340**	**Carry to summary**
1.11	**Provision of zone controls to heating system**					
	Installation of local room controls to existing heating systems including e.g. zone controls and time clocks	1	item	150,000	150,000	No detail, allowance per building
	BWIC with MEP Services	3	%		4,500	
	Testing & Commissioning	5	%		7,725	
	Subcontractor Preliminaries	12	%		19,467	
	Subtotal				**181,692**	
	Client Oncosts					
	Professional Fees	8	%		14,535	
	Client Risk/Contingency	10	%		19,623	
	VAT	20	%		43,170	
	Option Total				**259,020**	**Carry to summary**
1.12	**Provision of foil faced heat reflectors behind emitters on perimeter walls**					
	New foil faced heat reflectors behind emitters on perimeter walls, to include isolation and removal of heat emitter, installation of heat reflector, and reinstatement/making good	672	nr	300	201,600	Assume 1nr radiator per 15m2 of existing building GIFA
	BWIC with MEP Services	3	%		6,048	
	Testing & Commissioning	5	%		10,382	
	Subcontractor Preliminaries	12	%		26,164	
	Subtotal				**244,194**	
	Client Oncosts					
	Professional Fees	8	%		19,536	
	Client Risk/Contingency	10	%		26,373	
	VAT	20	%		58,021	
	Option Total				**348,123**	**Carry to summary**
1.13	**Thermal insulation improvements to heating infrastructure**					
	Allowance for removal of damaged & missing insulation, replacement with modern high performing insulation where required	1	item	50,000	50,000	No detail, allowance per building
	BWIC with MEP Services	3	%		1,500	
	Testing & Commissioning	5	%		2,575	
	Subcontractor Preliminaries	12	%		6,489	
	Subtotal				**60,564**	
	Client Oncosts					
	Professional Fees	8	%		4,845	
	Client Risk/Contingency	10	%		6,541	
	VAT	20	%		14,390	
	Option Total				**86,340**	**Carry to summary**
1.14	**Provision of side stream filtration**					
	New side stream filtration unit to heating system	1	item	35,000	35,000	No detail, allowance per building
	BWIC with MEP Services	3	%		1,050	
	Testing & Commissioning	5	%		1,803	
	Subcontractor Preliminaries	12	%		4,542	
	Subtotal				**42,395**	
	Client Oncosts					
	Professional Fees	8	%		3,392	
	Client Risk/Contingency	10	%		4,579	
	VAT	20	%		10,073	
	Option Total				**60,438**	**Carry to summary**
1.15	**Provision of new/enhanced BMS controls**					
	Stripping-out of existing BMS system	10,086	m2	3	30,258	
	New Building Management System / Local controls	10,086	item	40	403,440	
	BWIC with MEP Services	3	%		13,011	
	Testing & Commissioning	5	%		22,335	
	Subcontractor Preliminaries	12	%		56,285	
	Subtotal				**525,330**	
	Client Oncosts					

Item	Description	Qty	Unit	Rate	Total (£)	Comments
	Professional Fees	8	%		42,026	
	Client Risk/Contingency	10	%		56,736	
	VAT	20	%		124,818	
	Option Total				**748,910**	**Carry to summary**
1.16	**Provision of PV generation**					
	Photovoltaic panels; PV system including panels, fixing, DC and AC cabling, inverter, meters	165	m2	320	52,800	
	Allowance for making good, additional structural support etc	1	item	5,000	5,000	
	BWIC with MEP Services	3	%		1,734	
	Testing & Commissioning	5	%		2,977	
	Subcontractor Preliminaries	12	%		7,501	
	Subtotal				**70,012**	
	Client Oncosts					
	Professional Fees	8	%		5,601	
	Client Risk/Contingency	10	%		7,561	
	VAT	20	%		16,635	
	Option Total				**99,809**	**Carry to summary**
1.17	**Upgrade lighting to high efficiency LED fittings**					
	Removal and disposal of existing light fittings	5,135	m2	10	51,350	To area as noted within HL Schedule (not to full GIFA)
	New lighting fittings (replacement fittings only - no allowance for re-wiring)	5,135	m2	70	359,450	
	BWIC with MEP Services	3	%		12,324	
	Testing & Commissioning	5	%		21,156	
	Subcontractor Preliminaries	12	%		53,314	
	Subtotal				**497,594**	
	Client Oncosts					
	Professional Fees	8	%		39,808	
	Client Risk/Contingency	10	%		53,740	
	VAT	20	%		118,228	
	Option Total				**709,370**	**Carry to summary**
1.18	**Provision of automatic lighting controls throughout**					
	New automatic lighting controls throughout	10,086	m2	15	151,290	Assumed to full GIFA
	BWIC with MEP Services	3	%		4,539	
	Testing & Commissioning	5	%		7,791	
	Subcontractor Preliminaries	12	%		19,634	
	Subtotal				**183,255**	
	Client Oncosts					
	Professional Fees	8	%		14,660	
	Client Risk/Contingency	10	%		19,791	
	VAT	20	%		43,541	
	Option Total				**261,248**	**Carry to summary**
1.19	**Provision of Surveys**					
	Asbestos Survey	1	item	20,000	20,000	Survey only, no allowance for required works & removal
	Thermographic Survey	1	item	5,000	5,000	Survey only, no allowance for required works & removal
	Subtotal				**25,000**	
	Client Oncosts					
	Professional Fees				N/A	
	Client Risk/Contingency	10	%		2,500	
	VAT	20	%		5,500	
	Option Total				**33,000**	**Carry to summary**

Item	Description	Qty	Unit	Rate	Total (£)	Comments
2.1	**Roof insulation upgrade**					
	Remove & dispose of existing roof coverings	531	m2	5	2,655	
	Remove and reinstall rooftop plant to affected areas	1	item	25,000	25,000	Allowance only - required scope TBC
	New insulation and roof covering	531	m2	150	79,650	
	Subtotal				**107,305**	
	Client Oncosts					
	Professional Fees	8	%		8,584	
	Client Risk/Contingency	10	%		11,589	
	VAT	20	%		25,496	
	Option Total				**152,974**	**Carry to summary**
2.2	**Replace curtain walling system**					
	Remove existing cladding	2,233	m2	60	133,980	Quantity based on HL schedule for Walls plus Glazing (assume replacement of full envelope)
	Access/scaffold to full building	2,233	m2	80	178,640	
	New cladding to full building	2,233	m2	600	1,339,800	Blended rate (solid/glazed)
	Subtotal				**1,652,420**	
	Client Oncosts					
	Professional Fees	8	%		132,194	
	Client Risk/Contingency	10	%		178,461	
	VAT	20	%		392,615	
	Option Total				**2,355,690**	**Carry to summary**
2.3	**Remedial works from thermographic survey**					
	Unable to price at this stage due to lack of detail on required works				Excluded	
2.4	**High temperature air source heat pumps - disconnect building from heat network**					
	Air source heat pump; 22kW	4	nr	11,000	44,000	Assumes High Temperature load from HL Schedule, 4nr pumps at 30% of load capacity, totalling 120% of load
	Primary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	5,000	5,000	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	4,000	4,000	
	Pressurization unit and expansion vessel	1	nr	3,000	3,000	
	Dosing pot	1	item	750	750	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Assumes connection to existing main distribution pipework
	Plate heat exchanger	1	item	3,000	3,000	
	LV switchboard including new cabling etc	1	item	20,000	20,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		7,463	
	Testing & Commissioning	5	%		12,811	
	Subcontractor Preliminaries	12	%		32,283	
	Subtotal				**301,306**	
	Client Oncosts					
	Professional Fees	8	%		24,104	
	Client Risk/Contingency	10	%		32,541	
	VAT	20	%		71,590	
	Option Total				**429,542**	**Carry to summary**
2.5	**Low temperature air source heat pumps - disconnect building from heat network**					
	Removal of existing heat source, all distribution pipework, and emitters	1	item	25,000	25,000	
	Replacement of heat emitters and pipework	1	item	71,550	71,550	
	Air source heat pump; 22kW	4	nr	12,000	48,000	Assumes Low Temperature load from HL Schedule, 4nr pumps at 30% of load capacity, totalling 120% of load
	Primary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	5,000	5,000	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	4,000	4,000	
	Pressurization unit and expansion vessel	1	nr	3,000	3,000	
	Dosing pot	1	item	750	750	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Connection to new main distribution pipework above
	Plate heat exchanger	1	item	3,000	3,000	
	LV switchboard, including new cabling	1	item	20,000	20,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		10,479	
	Testing & Commissioning	5	%		17,989	
	Subcontractor Preliminaries	12	%		45,332	
	Subtotal				**423,100**	
	Client Oncosts					

Item	Description	Qty	Unit	Rate	Total (£)	Comments
	Professional Fees	8	%		33,848	
	Client Risk/Contingency	10	%		45,695	
	VAT	20	%		100,529	
	Option Total				**603,172**	**Carry to summary**
2.6	**Domestic hot water from high temperature heat pumps**					
	Air source heat pump; 30kW	1	nr	12,000	12,000	
	Primary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	5,000	5,000	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	4,000	4,000	
	Pressurization unit and expansion vessel	1	nr	3,000	3,000	
	Dosing pot	1	item	750	750	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Connection to new domestic hot water distribution pipework
	Plate heat exchanger	1	item	10,000	10,000	
	LV switchboard including new cabling etc	1	item	20,000	20,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	Removal of existing domestic hot water system	2,384	m2	1	2,384	
	Installation of domestic hot water system	2,384	m2	10	23,840	
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		7,499	
	Testing & Commissioning	5	%		12,874	
	Subcontractor Preliminaries	12	%		32,442	
	Subtotal				**302,789**	
	Client Oncosts					
	Professional Fees	8	%		24,223	
	Client Risk/Contingency	10	%		32,701	
	VAT	20	%		71,943	
	Option Total				**431,655**	**Carry to summary**
2.7	**Provision of zone controls to heating system**					
	Installation of local room controls to existing heating systems including e.g. zone controls and time clocks	1	item	50,000	50,000	No detail, allowance per building
	BWIC with MEP Services	3	%		1,500	
	Testing & Commissioning	5	%		2,575	
	Subcontractor Preliminaries	12	%		6,489	
	Subtotal				**60,564**	
	Client Oncosts					
	Professional Fees	8	%		4,845	
	Client Risk/Contingency	10	%		6,541	
	VAT	20	%		14,390	
	Option Total				**86,340**	**Carry to summary**
2.8	**Provision of foil faced heat reflectors behind emitters on perimeter walls**					
	New foil faced heat reflectors behind emitters on perimeter walls, to include isolation and removal of heat emitter, installation of heat reflector, and reinstatement/making good	159	nr	300	47,700	Assume 1nr radiator per 15m2 of existing building GIFA
	BWIC with MEP Services	3	%		1,431	
	Testing & Commissioning	5	%		2,457	
	Subcontractor Preliminaries	12	%		6,191	
	Subtotal				**57,778**	
	Client Oncosts					
	Professional Fees	8	%		4,622	
	Client Risk/Contingency	10	%		6,240	
	VAT	20	%		13,728	
	Option Total				**82,368**	**Carry to summary**
2.9	**Thermal insulation improvements to heating infrastructure**					
	Allowance for removal of damaged & missing insulation, replacement with modern high performing insulation where required	1	item	12,000	12,000	No detail, allowance per building
	BWIC with MEP Services	3	%		360	
	Testing & Commissioning	5	%		618	
	Subcontractor Preliminaries	12	%		1,557	
	Subtotal				**14,535**	
	Client Oncosts					
	Professional Fees	8	%		1,163	
	Client Risk/Contingency	10	%		1,570	
	VAT	20	%		3,454	
	Option Total				**20,722**	**Carry to summary**

Item	Description	Qty	Unit	Rate	Total (£)	Comments
2.10	**Provision of side stream filtration**					
	New side stream filtration unit to heating system	1	item	35,000	35,000	No detail, allowance per building
	BWIC with MEP Services	3	%		1,050	
	Testing & Commissioning	5	%		1,803	
	Subcontractor Preliminaries	12	%		4,542	
	Subtotal				**42,395**	
	Client Oncosts					
	Professional Fees	8	%		3,392	
	Client Risk/Contingency	10	%		4,579	
	VAT	20	%		10,073	
	Option Total				**60,438**	**Carry to summary**
2.11	**Provision of new/enhanced BMS controls**					
	Stripping-out of existing BMS system	2,384	m2	3	7,152	
	New Building Management System / Local controls	2,384	item	40	95,360	
	BWIC with MEP Services	3	%		3,075	
	Testing & Commissioning	5	%		5,279	
	Subcontractor Preliminaries	12	%		13,304	
	Subtotal				**124,171**	
	Client Oncosts					
	Professional Fees	8	%		9,934	
	Client Risk/Contingency	10	%		13,410	
	VAT	20	%		29,503	
	Option Total				**177,018**	**Carry to summary**
2.12	**Provision of PV generation**					
	Photovoltaic panels; PV system including panels, fixing, DC and AC cabling, inverter, meters	280	m2	320	89,600	
	Allowance for making good, additional structural support etc	1	item	5,000	5,000	
	BWIC with MEP Services	3	%		2,838	
	Testing & Commissioning	5	%		4,872	
	Subcontractor Preliminaries	12	%		12,277	
	Subtotal				**114,587**	
	Client Oncosts					
	Professional Fees	8	%		9,167	
	Client Risk/Contingency	10	%		12,375	
	VAT	20	%		27,226	
	Option Total				**163,355**	**Carry to summary**
2.13	**Upgrade lighting to high efficiency LED fittings**					
	Removal and disposal of existing light fittings	2,124	m2	10	21,240	To area as noted within HL Schedule (not to full GIFA)
	New lighting fittings (replacement fittings only - no allowance for re-wiring)	2,124	m2	70	148,680	
	BWIC with MEP Services	3	%		5,098	
	Testing & Commissioning	5	%		8,751	
	Subcontractor Preliminaries	12	%		22,052	
	Subtotal				**205,821**	
	Client Oncosts					
	Professional Fees	8	%		16,466	
	Client Risk/Contingency	10	%		22,229	
	VAT	20	%		48,903	
	Option Total				**293,418**	**Carry to summary**
2.14	**Provision of automatic lighting controls throughout**					
	New automatic lighting controls throughout	2,384	m2	15	35,760	Assumed to full GIFA
	BWIC with MEP Services	3	%		1,073	
	Testing & Commissioning	5	%		1,842	
	Subcontractor Preliminaries	12	%		4,641	
	Subtotal				**43,315**	
	Client Oncosts					
	Professional Fees	8	%		3,465	
	Client Risk/Contingency	10	%		4,678	
	VAT	20	%		10,292	
	Option Total				**61,750**	**Carry to summary**
2.15	**Provision of Surveys**					
	Asbestos Survey	1	item	10,000	10,000	Survey only, no allowance for required works & removal
	Thermographic Survey	1	item	5,000	5,000	Survey only, no allowance for required works & removal
	Subtotal				**15,000**	
	Client Oncosts					
	Professional Fees				N/A	
	Client Risk/Contingency	10	%		1,500	
	VAT	20	%		3,300	

Item	Description	Qty	Unit	Rate	Total (£)	Comments
	Option Total				19,800	Carry to summary

Item	Description	Qty	Unit	Rate	Total (£)	Comments
3.1	**Roof insulation upgrade**					
	Remove & dispose of existing roof coverings	1,462	m2	5	7,310	
	Remove and reinstall rooftop plant to affected areas	1	item	25,000	25,000	Allowance only - required scope TBC
	New insulation and roof covering	1,462	m2	150	219,300	
	Subtotal				**251,610**	
	Client Oncosts					
	Professional Fees	8	%		20,129	
	Client Risk/Contingency	10	%		27,174	
	VAT	20	%		59,783	
	Option Total				**358,695**	**Carry to summary**
3.2	**Replace curtain walling system**					
	Remove existing cladding	3,300	m2	60	198,000	Quantity based on HL schedule for Walls plus Glazing (assume replacement of full envelope)
	Access/scaffold to full building	3,300	m2	80	264,000	
	New cladding to full building	3,300	m2	600	1,980,000	Blended rate (solid/glazed)
	Subtotal				**2,442,000**	
	Client Oncosts					
	Professional Fees	8	%		195,360	
	Client Risk/Contingency	10	%		263,736	
	VAT	20	%		580,219	
	Option Total				**3,481,315**	**Carry to summary**
3.3	**Remedial works from thermographic survey**					
	Unable to price at this stage due to lack of detail on required works				Excluded	
3.4	**Replace single glazed units with double glazing**					
	Remove existing glazing	462	m2	60	27,720	Stairwell areas only
	Access/scaffold to affected areas	462	m2	80	36,960	
	New double glazed units	462	m2	700	323,400	
	Subtotal				**388,080**	
	Client Oncosts					
	Professional Fees	8	%		31,046	
	Client Risk/Contingency	10	%		41,913	
	VAT	20	%		92,208	
	Option Total				**553,247**	**Carry to summary**
3.5	**Refurbishment of existing window units**					
	Remedial works to existing windows; adjusting frames and seals, minor repairs, cracked panes, ironmongery adjustment, making good - cost per window	311	nr	250	77,750	
	Subtotal				**77,750**	
	Client Oncosts					
	Professional Fees	8	%		6,220	
	Client Risk/Contingency	10	%		8,397	
	VAT	20	%		18,473	
	Option Total				**110,840**	**Carry to summary**
3.6	**High temperature air source heat pumps - disconnect building from heat network**					
	Air source heat pump; 41kW	4	nr	13,000	52,000	Assumes High Temperature load from HL Schedule, 4nr pumps at 30% of load capacity, totalling 120% of load
	Primary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	5,000	5,000	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	4,000	4,000	
	Pressurization unit and expansion vessel	1	nr	3,000	3,000	
	Dosing pot	1	item	750	750	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Assumes connection to existing main distribution pipework
	Plate heat exchanger	1	item	3,000	3,000	
	LV switchboard including new cabling etc	1	item	20,000	20,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		7,703	
	Testing & Commissioning	5	%		13,223	
	Subcontractor Preliminaries	12	%		33,321	
	Subtotal				**310,996**	
	Client Oncosts					
	Professional Fees	8	%		24,880	
	Client Risk/Contingency	10	%		33,588	
	VAT	20	%		73,893	

Item	Description	Qty	Unit	Rate	Total (£)	Comments
	Option Total				**443,356**	**Carry to summary**
3.7	**Low temperature air source heat pumps - disconnect building from heat network**					
	Removal of existing heat source, all distribution pipework, and emitters	1	item	25,000	25,000	
	Replacement of heat emitters and pipework	1	item	157,050	157,050	
	Air source heat pump; 41kW	4	nr	13,000	52,000	Assumes Low Temperature load from HL Schedule, 4nr pumps at 30% of load capacity, totalling 120% of load
	Primary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	5,000	5,000	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	4,000	4,000	
	Pressurization unit and expansion vessel	1	nr	3,000	3,000	
	Dosing pot	1	item	750	750	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Connection to new main distribution pipework above
	Plate heat exchanger	1	item	3,000	3,000	
	LV switchboard, including new cabling	1	item	20,000	20,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		13,164	
	Testing & Commissioning	5	%		22,598	
	Subcontractor Preliminaries	12	%		56,947	
	Subtotal				**531,510**	
	Client Oncosts					
	Professional Fees	8	%		42,521	
	Client Risk/Contingency	10	%		57,403	
	VAT	20	%		126,287	
	Option Total				**757,720**	**Carry to summary**
3.8	**Domestic hot water from high temperature heat pumps**					
	Air source heat pump; 81kW	1	nr	28,000	28,000	
	Primary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	5,000	5,000	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	4,000	4,000	
	Pressurization unit and expansion vessel	1	nr	3,000	3,000	
	Dosing pot	1	item	750	750	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Connection to new domestic hot water distribution pipework
	Plate heat exchanger	1	item	10,000	10,000	
	LV switchboard including new cabling etc	1	item	20,000	20,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	Removal of existing domestic hot water system	5,233	m2	1	5,233	
	Installation of domestic hot water system	5,233	m2	10	52,330	
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		8,919	
	Testing & Commissioning	5	%		15,312	
	Subcontractor Preliminaries	12	%		38,585	
	Subtotal				**360,129**	
	Client Oncosts					
	Professional Fees	8	%		28,810	
	Client Risk/Contingency	10	%		38,894	
	VAT	20	%		85,567	
	Option Total				**513,400**	**Carry to summary**
3.9	**Provision of zone controls to heating system**					
	Installation of local room controls to existing heating systems including e.g. zone controls and time clocks	1	item	50,000	50,000	No detail, allowance per building
	BWIC with MEP Services	3	%		1,500	
	Testing & Commissioning	5	%		2,575	
	Subcontractor Preliminaries	12	%		6,489	
	Subtotal				**60,564**	
	Client Oncosts					
	Professional Fees	8	%		4,845	
	Client Risk/Contingency	10	%		6,541	
	VAT	20	%		14,390	
	Option Total				**86,340**	**Carry to summary**
3.10	**Provision of foil faced heat reflectors behind emitters on perimeter walls**					
	New foil faced heat reflectors behind emitters on perimeter walls, to include isolation and removal of heat emitter, installation of heat reflector, and reinstatement/making good	349	nr	300	104,700	Assume 1nr radiator per 15m2 of existing building GIFA
	BWIC with MEP Services	3	%		3,141	

Item	Description	Qty	Unit	Rate	Total (£)	Comments
	Testing & Commissioning	5	%		5,392	
	Subcontractor Preliminaries	12	%		13,588	
	Subtotal				**126,821**	
	Client Oncosts					
	Professional Fees	8	%		10,146	
	Client Risk/Contingency	10	%		13,697	
	VAT	20	%		30,133	
	Option Total				**180,796**	**Carry to summary**
3.11	**Thermal insulation improvements to heating infrastructure**					
	Allowance for removal of damaged & missing insulation, replacement with modern high performing insulation where required	1	item	26,000	26,000	No detail, allowance per building
	BWIC with MEP Services	3	%		780	
	Testing & Commissioning	5	%		1,339	
	Subcontractor Preliminaries	12	%		3,374	
	Subtotal				**31,493**	
	Client Oncosts					
	Professional Fees	8	%		2,519	
	Client Risk/Contingency	10	%		3,401	
	VAT	20	%		7,483	
	Option Total				**44,897**	**Carry to summary**
3.12	**Provision of side stream filtration**					
	New side stream filtration unit to heating system	1	item	35,000	35,000	No detail, allowance per building
	BWIC with MEP Services	3	%		1,050	
	Testing & Commissioning	5	%		1,803	
	Subcontractor Preliminaries	12	%		4,542	
	Subtotal				**42,395**	
	Client Oncosts					
	Professional Fees	8	%		3,392	
	Client Risk/Contingency	10	%		4,579	
	VAT	20	%		10,073	
	Option Total				**60,438**	**Carry to summary**
3.13	**Provision of new/enhanced BMS controls**					
	Stripping-out of existing BMS system	5,233	m2	3	15,699	
	New Building Management System / Local controls	5,233	item	40	209,320	
	BWIC with MEP Services	3	%		6,751	
	Testing & Commissioning	5	%		11,588	
	Subcontractor Preliminaries	12	%		29,203	
	Subtotal				**272,561**	
	Client Oncosts					
	Professional Fees	8	%		21,805	
	Client Risk/Contingency	10	%		29,437	
	VAT	20	%		64,760	
	Option Total				**388,563**	**Carry to summary**
3.14	**Provision of PV generation**					
	Photovoltaic panels; PV system including panels, fixing, DC and AC cabling, inverter, meters	540	m2	320	172,800	
	Allowance for making good, additional structural support etc	1	item	5,000	5,000	
	BWIC with MEP Services	3	%		5,334	
	Testing & Commissioning	5	%		9,157	
	Subcontractor Preliminaries	12	%		23,075	
	Subtotal				**215,366**	
	Client Oncosts					
	Professional Fees	8	%		17,229	
	Client Risk/Contingency	10	%		23,259	
	VAT	20	%		51,171	
	Option Total				**307,025**	**Carry to summary**
3.15	**Upgrade lighting to high efficiency LED fittings**					
	Removal and disposal of existing light fittings	852	m2	10	8,520	To area as noted within HL Schedule (not to full GIFA)
	New lighting fittings (replacement fittings only - no allowance for re-wiring)	852	m2	70	59,640	
	BWIC with MEP Services	3	%		2,045	
	Testing & Commissioning	5	%		3,510	
	Subcontractor Preliminaries	12	%		8,846	
	Subtotal				**82,561**	
	Client Oncosts					
	Professional Fees	8	%		6,605	

Item	Description	Qty	Unit	Rate	Total (£)	Comments
	Client Risk/Contingency	10	%		8,917	
	VAT	20	%		19,616	
	Option Total				**117,699**	**Carry to summary**
3.16	**Provision of automatic lighting controls throughout**					
	New automatic lighting controls throughout	5,233	m2	15	78,495	Assumed to full GIFA
	BWIC with MEP Services	3	%		2,355	
	Testing & Commissioning	5	%		4,042	
	Subcontractor Preliminaries	12	%		10,187	
	Subtotal				**95,079**	
	Client Oncosts					
	Professional Fees	8	%		7,606	
	Client Risk/Contingency	10	%		10,269	
	VAT	20	%		22,591	
	Option Total				**135,545**	**Carry to summary**
3.17	**Provision of Surveys**					
	Asbestos Survey	1	item	10,000	10,000	Survey only, no allowance for required works & removal
	Thermographic Survey	1	item	5,000	5,000	Survey only, no allowance for required works & removal
	Subtotal				**15,000**	
	Client Oncosts					
	Professional Fees				N/A	
	Client Risk/Contingency	10	%		1,500	
	VAT	20	%		3,300	
	Option Total				**19,800**	**Carry to summary**

Item	Description	Qty	Unit	Rate	Total (£)	Comments
4.1	**Roof insulation upgrade**					
	Remove & dispose of existing roof coverings	1,330	m2	5	6,650	
	Remove and reinstall rooftop plant to affected areas	1	item	25,000	25,000	Allowance only - required scope TBC
	New insulation and roof covering	1,330	m2	150	199,500	
	Subtotal				**231,150**	
	Client Oncosts					
	Professional Fees	8	%		18,492	
	Client Risk/Contingency	10	%		24,964	
	VAT	20	%		54,921	
	Option Total				**329,527**	**Carry to summary**
4.2	**Replace curtain walling system**					
	Remove existing cladding	2,418	m2	60	145,080	Quantity based on HL schedule for Walls plus Glazing (assume replacement of full envelope)
	Access/scaffold to full building	2,418	m2	80	193,440	
	New cladding to full building	2,418	m2	600	1,450,800	Blended rate (solid/glazed)
	Subtotal				**1,789,320**	
	Client Oncosts					
	Professional Fees	8	%		143,146	
	Client Risk/Contingency	10	%		193,247	
	VAT	20	%		425,142	
	Option Total				**2,550,855**	**Carry to summary**
4.3	**Replace single glazed units with double glazing**					
	Remove existing glazing	716	m2	60	42,960	Quantity based on full glazing area as per Hoare Lea Schedule
	Access/scaffold to affected areas	716	m2	80	57,280	
	New double glazed units	716	m2	700	501,200	
	Subtotal				**601,440**	
	Client Oncosts					
	Professional Fees	8	%		48,115	
	Client Risk/Contingency	10	%		64,956	
	VAT	20	%		142,902	
	Option Total				**857,413**	**Carry to summary**
4.4	**Refurbishment of existing window units**					
	Remedial works to existing windows; adjusting frames and seals, minor repairs, cracked panes, ironmongery adjustment, making good - cost per window	161	nr	250	40,250	
	Subtotal				**40,250**	
	Client Oncosts					
	Professional Fees	8	%		3,220	
	Client Risk/Contingency	10	%		4,347	
	VAT	20	%		9,563	
	Option Total				**57,380**	**Carry to summary**
4.5	**Remedial works from thermographic survey**					
	Unable to price at this stage due to lack of detail on required works				Excluded	
4.6	**Low temperature air source heat pumps in lead capacity with gas fired plant**					
	Air source heat pump; 129kW	4	nr	47,000	188,000	Assumes Low Temperature load from HL Schedule, 4nr pumps at 30% of load capacity, totalling 120% of load
	Primary heating water circulation pumps	1	item	10,000	10,000	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	12,000	12,000	
	Pressurization unit and expansion vessel	1	nr	5,000	5,000	
	Dosing pot	1	item	1,000	1,000	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Assumes connection to existing main distribution pipework
	Plate heat exchanger	1	item	10,000	10,000	
	LV switchboard including new cabling etc	1	item	50,000	50,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		13,350	
	Testing & Commissioning	5	%		22,918	
	Subcontractor Preliminaries	12	%		57,752	
	Subtotal				**539,020**	
	Client Oncosts					
	Professional Fees	8	%		43,122	
	Client Risk/Contingency	10	%		58,214	
	VAT	20	%		128,071	

Item	Description	Qty	Unit	Rate	Total (£)	Comments
	Option Total				**768,426**	**Carry to summary**
4.7	**Low Temperature air source heat pumps replacing gas fired plant**					
	Removal of existing heat source, all distribution pipework, and emitters	1	item	25,000	25,000	
	Replacement of heat emitters and pipework	1	item	109,350	109,350	
	Air source heat pump; 129kW	4	nr	47,000	188,000	Assumes Low Temperature load from HL Schedule, 4nr pumps at 30% of load capacity, totalling 120% of load
	Primary heating water circulation pumps	1	item	10,000	10,000	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	12,000	12,000	
	Pressurization unit and expansion vessel	1	nr	5,000	5,000	
	Dosing pot	1	item	1,000	1,000	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Connection to new main distribution pipework above
	Plate heat exchanger	1	item	10,000	10,000	
	LV switchboard, including new cabling	1	item	50,000	50,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		17,381	
	Testing & Commissioning	5	%		29,837	
	Subcontractor Preliminaries	12	%		75,188	
	Subtotal				**701,755**	
	Client Oncosts					
	Professional Fees	8	%		56,140	
	Client Risk/Contingency	10	%		75,790	
	VAT	20	%		166,737	
	Option Total				**1,000,422**	**Carry to summary**
4.8	**High Temperature air source heat pumps replacing gas fired plant**					
	Removal of existing heat source	1	item	5,000	5,000	
	Air source heat pump; 129kW	4	nr	47,000	188,000	Assumes High Temperature load from HL Schedule, 4nr pumps at 30% of load capacity, totalling 120% of load
	Primary heating water circulation pumps	1	item	10,000	10,000	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	12,000	12,000	
	Pressurization unit and expansion vessel	1	nr	5,000	5,000	
	Dosing pot	1	item	1,000	1,000	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Assumes connection to existing main distribution pipework
	Plate heat exchanger	1	item	10,000	10,000	
	LV switchboard including new cabling etc	1	item	50,000	50,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		13,350	
	Testing & Commissioning	5	%		22,918	
	Subcontractor Preliminaries	12	%		57,752	
	Subtotal				**544,020**	
	Client Oncosts					
	Professional Fees	8	%		43,522	
	Client Risk/Contingency	10	%		58,754	
	VAT	20	%		129,259	
	Option Total				**775,554**	**Carry to summary**
4.9	**Domestic hot water from high temperature heat pumps**					
	Air source heat pump; 62kW	1	nr	26,000	26,000	
	Primary heating water circulation pumps	1	item	10,000	10,000	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	12,000	12,000	
	Pressurization unit and expansion vessel	1	nr	5,000	5,000	
	Dosing pot	1	item	1,000	1,000	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Connection to new domestic hot water distribution pipework
	Plate heat exchanger	1	item	10,000	10,000	
	LV switchboard including new cabling etc	1	item	20,000	20,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	Removal of existing domestic hot water system	3,652	m2	1	3,652	
	Installation of domestic hot water system	3,652	m2	10	36,520	
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		8,795	
	Testing & Commissioning	5	%		15,098	
	Subcontractor Preliminaries	12	%		38,048	

Item	Description	Qty	Unit	Rate	Total (£)	Comments
	Subtotal				**355,113**	
	Client Oncosts					
	Professional Fees	8	%		28,409	
	Client Risk/Contingency	10	%		38,352	
	VAT	20	%		84,375	
	Option Total				**506,250**	**Carry to summary**
4.10	**Provision of zone controls to heating system**					
	Installation of local room controls to existing heating systems including e.g. zone controls and time clocks	1	item	50,000	50,000	No detail, allowance per building
	BWIC with MEP Services	3	%		1,500	
	Testing & Commissioning	5	%		2,575	
	Subcontractor Preliminaries	12	%		6,489	
	Subtotal				**60,564**	
	Client Oncosts					
	Professional Fees	8	%		4,845	
	Client Risk/Contingency	10	%		6,541	
	VAT	20	%		14,390	
	Option Total				**86,340**	**Carry to summary**
4.11	**Provision of foil faced heat reflectors behind emitters on perimeter walls**					
	New foil faced heat reflectors behind emitters on perimeter walls, to include isolation and removal of heat emitter, installation of heat reflector, and reinstatement/making good	243	nr	300	72,900	Assume 1nr radiator per 15m2 of existing building GIFA
	BWIC with MEP Services	3	%		2,187	
	Testing & Commissioning	5	%		3,754	
	Subcontractor Preliminaries	12	%		9,461	
	Subtotal				**88,302**	
	Client Oncosts					
	Professional Fees	8	%		7,064	
	Client Risk/Contingency	10	%		9,537	
	VAT	20	%		20,981	
	Option Total				**125,884**	**Carry to summary**
4.12	**Thermal insulation improvements to heating infrastructure**					
	Allowance for removal of damaged & missing insulation, replacement with modern high performing insulation where required	1	item	18,000	18,000	No detail, allowance per building
	BWIC with MEP Services	3	%		540	
	Testing & Commissioning	5	%		927	
	Subcontractor Preliminaries	12	%		2,336	
	Subtotal				**21,803**	
	Client Oncosts					
	Professional Fees	8	%		1,744	
	Client Risk/Contingency	10	%		2,355	
	VAT	20	%		5,180	
	Option Total				**31,082**	**Carry to summary**
4.13	**Provision of side stream filtration**					
	New side stream filtration unit to heating system	1	item	35,000	35,000	No detail, allowance per building
	BWIC with MEP Services	3	%		1,050	
	Testing & Commissioning	5	%		1,803	
	Subcontractor Preliminaries	12	%		4,542	
	Subtotal				**42,395**	
	Client Oncosts					
	Professional Fees	8	%		3,392	
	Client Risk/Contingency	10	%		4,579	
	VAT	20	%		10,073	
	Option Total				**60,438**	**Carry to summary**
4.14	**Provision of new/enhanced BMS controls**					
	Stripping-out of existing BMS system	3,652	m2	3	10,956	
	New Building Management System / Local controls	3,652	item	40	146,080	
	BWIC with MEP Services	3	%		4,711	
	Testing & Commissioning	5	%		8,087	
	Subcontractor Preliminaries	12	%		20,380	
	Subtotal				**190,215**	
	Client Oncosts					

Item	Description	Qty	Unit	Rate	Total (£)	Comments
	Professional Fees	8	%		15,217	
	Client Risk/Contingency	10	%		20,543	
	VAT	20	%		45,195	
	Option Total				**271,170**	**Carry to summary**
4.15	**Provision of PV generation**					
	Photovoltaic panels; PV system including panels, fixing, DC and AC cabling, inverter, meters	346	m2	320	110,720	
	Allowance for making good, additional structural support etc	1	item	5,000	5,000	
	BWIC with MEP Services	3	%		3,472	
	Testing & Commissioning	5	%		5,960	
	Subcontractor Preliminaries	12	%		15,018	
	Subtotal				**140,169**	
	Client Oncosts					
	Professional Fees	8	%		11,214	
	Client Risk/Contingency	10	%		15,138	
	VAT	20	%		33,304	
	Option Total				**199,825**	**Carry to summary**
4.16	**Upgrade lighting to high efficiency LED fittings**					
	Removal and disposal of existing light fittings	2,417	m2	10	24,170	To area as noted within HL Schedule (not to full GIFA)
	New lighting fittings (replacement fittings only - no allowance for re-wiring)	2,417	m2	70	169,190	
	BWIC with MEP Services	3	%		5,801	
	Testing & Commissioning	5	%		9,958	
	Subcontractor Preliminaries	12	%		25,094	
	Subtotal				**234,213**	
	Client Oncosts					
	Professional Fees	8	%		18,737	
	Client Risk/Contingency	10	%		25,295	
	VAT	20	%		55,649	
	Option Total				**333,894**	**Carry to summary**
4.17	**Provision of automatic lighting controls throughout**					
	New automatic lighting controls throughout	3,652	m2	15	54,780	Assumed to full GIFA
	BWIC with MEP Services	3	%		1,643	
	Testing & Commissioning	5	%		2,821	
	Subcontractor Preliminaries	12	%		7,109	
	Subtotal				**66,354**	
	Client Oncosts					
	Professional Fees	8	%		5,308	
	Client Risk/Contingency	10	%		7,166	
	VAT	20	%		15,766	
	Option Total				**94,594**	**Carry to summary**
4.18	**Provision of Surveys**					
	Asbestos Survey	1	item	10,000	10,000	Survey only, no allowance for required works & removal
	Thermographic Survey	1	item	5,000	5,000	Survey only, no allowance for required works & removal
	Subtotal				**15,000**	
	Client Oncosts					
	Professional Fees				N/A	
	Client Risk/Contingency	10	%		1,500	
	VAT	20	%		3,300	
	Option Total				**19,800**	**Carry to summary**

Item	Description	Qty	Unit	Rate	Total (£)	Comments
5.1	**High temperature air source heat pumps - disconnect building from heat network**					
	Air source heat pump; 48kW	4	nr	15,000	60,000	Assumes High Temperature load from HL Schedule, 4nr pumps at 30% of load capacity, totalling 120% of load
	Primary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	5,000	5,000	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	4,000	4,000	
	Pressurization unit and expansion vessel	1	nr	3,000	3,000	
	Dosing pot	1	item	750	750	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Assumes connection to existing main distribution pipework
	Plate heat exchanger	1	item	3,000	3,000	
	LV switchboard including new cabling etc	1	item	20,000	20,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		7,943	
	Testing & Commissioning	5	%		13,635	
	Subcontractor Preliminaries	12	%		34,359	
	Subtotal				**320,686**	
	Client Oncosts					
	Professional Fees	8	%		25,655	
	Client Risk/Contingency	10	%		34,634	
	VAT	20	%		76,195	
	Option Total				**457,171**	**Carry to summary**
5.2	**Low temperature air source heat pumps - disconnect building from heat network**					
	Removal of existing heat source, all distribution pipework, and emitters	1	item	25,000	25,000	
	Replacement of heat emitters and pipework	1	item	125,100	125,100	
	Air source heat pump; 48kW	4	nr	15,000	60,000	Assumes Low Temperature load from HL Schedule, 4nr pumps at 30% of load capacity, totalling 120% of load
	Primary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	5,000	5,000	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	4,000	4,000	
	Pressurization unit and expansion vessel	1	nr	3,000	3,000	
	Dosing pot	1	item	750	750	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Connection to new main distribution pipework above
	Plate heat exchanger	1	item	3,000	3,000	
	LV switchboard, including new cabling	1	item	20,000	20,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		12,446	
	Testing & Commissioning	5	%		21,365	
	Subcontractor Preliminaries	12	%		53,839	
	Subtotal				**502,500**	
	Client Oncosts					
	Professional Fees	8	%		40,200	
	Client Risk/Contingency	10	%		54,270	
	VAT	20	%		119,394	
	Option Total				**716,363**	**Carry to summary**
5.3	**Replacement of fixed speed drives**					
	Removal of existing variable speed drives, and replace with new high efficiency generation drives	1	item	20,000	20,000	No detail, allowance per building
	BWIC with MEP Services	3	%		600	
	Testing & Commissioning	5	%		1,030	
	Subcontractor Preliminaries	12	%		2,596	
	Subtotal				**24,226**	
	Client Oncosts					
	Professional Fees	8	%		1,938	
	Client Risk/Contingency	10	%		2,616	
	VAT	20	%		5,756	
	Option Total				**34,536**	**Carry to summary**
5.4	**Provision of zone controls to heating system**					
	Installation of local room controls to existing heating systems including e.g. zone controls and time clocks	1	item	50,000	50,000	No detail, allowance per building
	BWIC with MEP Services	3	%		1,500	
	Testing & Commissioning	5	%		2,575	
	Subcontractor Preliminaries	12	%		6,489	

Item	Description	Qty	Unit	Rate	Total (£)	Comments
	Subtotal				**60,564**	
	Client Oncosts					
	Professional Fees	8	%		4,845	
	Client Risk/Contingency	10	%		6,541	
	VAT	20	%		14,390	
	Option Total				**86,340**	**Carry to summary**
5.5	**Provision of foil faced heat reflectors behind emitters on perimeter walls**					
	New foil faced heat reflectors behind emitters on perimeter walls, to include isolation and removal of heat emitter, installation of heat reflector, and reinstatement/making good	278	nr	300	83,400	Assume 1nr radiator per 15m2 of existing building GIFA
	BWIC with MEP Services	3	%		2,502	
	Testing & Commissioning	5	%		4,295	
	Subcontractor Preliminaries	12	%		10,824	
	Subtotal				**101,021**	
	Client Oncosts					
	Professional Fees	8	%		8,082	
	Client Risk/Contingency	10	%		10,910	
	VAT	20	%		24,003	
	Option Total				**144,015**	**Carry to summary**
5.6	**Provision of side stream filtration**					
	New side stream filtration unit to heating system	1	item	35,000	35,000	No detail, allowance per building
	BWIC with MEP Services	3	%		1,050	
	Testing & Commissioning	5	%		1,803	
	Subcontractor Preliminaries	12	%		4,542	
	Subtotal				**42,395**	
	Client Oncosts					
	Professional Fees	8	%		3,392	
	Client Risk/Contingency	10	%		4,579	
	VAT	20	%		10,073	
	Option Total				**60,438**	**Carry to summary**
5.7	**Provision of new/enhanced BMS controls**					
	Stripping-out of existing BMS system	4,165	m2	3	12,495	
	New Building Management System / Local controls	4,165	item	40	166,600	
	BWIC with MEP Services	3	%		5,373	
	Testing & Commissioning	5	%		9,223	
	Subcontractor Preliminaries	12	%		23,243	
	Subtotal				**216,934**	
	Client Oncosts					
	Professional Fees	8	%		17,355	
	Client Risk/Contingency	10	%		23,429	
	VAT	20	%		51,544	
	Option Total				**309,261**	**Carry to summary**
5.8	**Provision of PV generation**					
	Photovoltaic panels; PV system including panels, fixing, DC and AC cabling, inverter, meters	240	m2	320	76,800	
	Allowance for making good, additional structural support etc	1	item	5,000	5,000	
	BWIC with MEP Services	3	%		2,454	
	Testing & Commissioning	5	%		4,213	
	Subcontractor Preliminaries	12	%		10,616	
	Subtotal				**99,083**	
	Client Oncosts					
	Professional Fees	8	%		7,927	
	Client Risk/Contingency	10	%		10,701	
	VAT	20	%		23,542	
	Option Total				**141,252**	**Carry to summary**
5.9	**Upgrade lighting to high efficiency LED fittings**					
	Removal and disposal of existing light fittings	1,516	m2	10	15,160	To area as noted within HL Schedule (not to full GIFA)
	New lighting fittings (replacement fittings only - no allowance for re-wiring)	1,516	m2	70	106,120	
	BWIC with MEP Services	3	%		3,638	
	Testing & Commissioning	5	%		6,246	
	Subcontractor Preliminaries	12	%		15,740	
	Subtotal				**146,904**	
	Client Oncosts					
	Professional Fees	8	%		11,752	
	Client Risk/Contingency	10	%		15,866	
	VAT	20	%		34,904	

Item	Description	Qty	Unit	Rate	Total (£)	Comments
	Option Total				**209,426**	**Carry to summary**
5.10	**Provision of automatic lighting controls throughout**					
	New automatic lighting controls throughout	4,165	m2	15	62,475	Assumed to full GIFA
	BWIC with MEP Services	3	%		1,874	
	Testing & Commissioning	5	%		3,217	
	Subcontractor Preliminaries	12	%		8,108	
	Subtotal				**75,675**	
	Client Oncosts					
	Professional Fees	8	%		6,054	
	Client Risk/Contingency	10	%		8,173	
	VAT	20	%		17,980	
	Option Total				**107,882**	**Carry to summary**

Item	Description	Qty	Unit	Rate	Total (£)	Comments
6.1	**High temperature air source heat pumps - disconnect building from heat network**					
	Air source heat pump; 26kW	4	nr	12,000	48,000	Assumes High Temperature load from HL Schedule, 4nr pumps at 30% of load capacity, totalling 120% of load
	Primary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	5,000	5,000	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	4,000	4,000	
	Pressurization unit and expansion vessel	1	nr	3,000	3,000	
	Dosing pot	1	item	750	750	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Assumes connection to existing main distribution pipework
	Plate heat exchanger	1	item	3,000	3,000	
	LV switchboard including new cabling etc	1	item	20,000	20,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		7,583	
	Testing & Commissioning	5	%		13,017	
	Subcontractor Preliminaries	12	%		32,802	
	Subtotal				**306,151**	
	Client Oncosts					
	Professional Fees	8	%		24,492	
	Client Risk/Contingency	10	%		33,064	
	VAT	20	%		72,741	
	Option Total				**436,449**	**Carry to summary**
6.2	**Low temperature air source heat pumps - disconnect building from heat network**					
	Removal of existing heat source, all distribution pipework, and emitters	1	item	25,000	25,000	
	Replacement of heat emitters and pipework	1	item	51,300	51,300	
	Air source heat pump; 26kW	4	nr	12,000	48,000	Assumes Low Temperature load from HL Schedule, 4nr pumps at 30% of load capacity, totalling 120% of load
	Primary heating water circulation pumps	1	item	7,500	7,500	2 no (1 duty and 1 standby)
	Secondary heating water circulation pumps	1	item	5,000	5,000	2 no (1 duty and 1 standby)
	LTHW buffer vessel	1	item	4,000	4,000	
	Pressurization unit and expansion vessel	1	nr	3,000	3,000	
	Dosing pot	1	item	750	750	
	Air/dirt separator	1	item	500	500	
	Pipework, ancillaries and valves; including thermal insulation	1	item	20,000	20,000	Connection to new main distribution pipework above
	Plate heat exchanger	1	item	3,000	3,000	
	LV switchboard, including new cabling	1	item	20,000	20,000	
	Allowance for power supplies to mechanical equipment	1	item	16,000	16,000	
	BMS Interventions	1	item	25,000	25,000	
	Allowance for gantry/plant adjustment/slabs & screens etc to enable ASHP installation	1	item	100,000	100,000	Allowance only, scope TBC
	BWIC with MEP Services	3	%		9,872	
	Testing & Commissioning	5	%		16,946	
	Subcontractor Preliminaries	12	%		42,704	
	Subtotal				**398,572**	
	Client Oncosts					
	Professional Fees	8	%		31,886	
	Client Risk/Contingency	10	%		43,046	
	VAT	20	%		94,701	
	Option Total				**568,204**	**Carry to summary**
6.3	**Replacement of fixed speed drives**					
	Removal of existing variable speed drives, and replace with new high efficiency generation drives	1	item	20,000	20,000	No detail, allowance per building
	BWIC with MEP Services	3	%		600	
	Testing & Commissioning	5	%		1,030	
	Subcontractor Preliminaries	12	%		2,596	
	Subtotal				**24,226**	
	Client Oncosts					
	Professional Fees	8	%		1,938	
	Client Risk/Contingency	10	%		2,616	
	VAT	20	%		5,756	
	Option Total				**34,536**	**Carry to summary**
6.4	**Provision of zone controls to heating system**					
	Installation of local room controls to existing heating systems including e.g. zone controls and time clocks	1	item	50,000	50,000	No detail, allowance per building
	BWIC with MEP Services	3	%		1,500	
	Testing & Commissioning	5	%		2,575	
	Subcontractor Preliminaries	12	%		6,489	

Item	Description	Qty	Unit	Rate	Total (£)	Comments
	Subtotal				**60,564**	
	Client Oncosts					
	Professional Fees	8	%		4,845	
	Client Risk/Contingency	10	%		6,541	
	VAT	20	%		14,390	
	Option Total				**86,340**	**Carry to summary**
6.5	**Provision of foil faced heat reflectors behind emitters on perimeter walls**					
	New foil faced heat reflectors behind emitters on perimeter walls, to include isolation and removal of heat emitter, installation of heat reflector, and reinstatement/making good	114	nr	300	34,200	Assume 1nr radiator per 15m2 of existing building GIFA
	BWIC with MEP Services	3	%		1,026	
	Testing & Commissioning	5	%		1,761	
	Subcontractor Preliminaries	12	%		4,438	
	Subtotal				**41,426**	
	Client Oncosts					
	Professional Fees	8	%		3,314	
	Client Risk/Contingency	10	%		4,474	
	VAT	20	%		9,843	
	Option Total				**59,057**	**Carry to summary**
6.6	**Provision of side stream filtration**					
	New side stream filtration unit to heating system	1	item	35,000	35,000	No detail, allowance per building
	BWIC with MEP Services	3	%		1,050	
	Testing & Commissioning	5	%		1,803	
	Subcontractor Preliminaries	12	%		4,542	
	Subtotal				**42,395**	
	Client Oncosts					
	Professional Fees	8	%		3,392	
	Client Risk/Contingency	10	%		4,579	
	VAT	20	%		10,073	
	Option Total				**60,438**	**Carry to summary**
6.7	**Provision of new/enhanced BMS controls**					
	Stripping-out of existing BMS system	1,709	m2	3	5,127	
	New Building Management System / Local controls	1,709	item	40	68,360	
	BWIC with MEP Services	3	%		2,205	
	Testing & Commissioning	5	%		3,785	
	Subcontractor Preliminaries	12	%		9,537	
	Subtotal				**89,013**	
	Client Oncosts					
	Professional Fees	8	%		7,121	
	Client Risk/Contingency	10	%		9,613	
	VAT	20	%		21,150	
	Option Total				**126,897**	**Carry to summary**
6.8	**Provision of PV generation**					
	Photovoltaic panels; PV system including panels, fixing, DC and AC cabling, inverter, meters	200	m2	320	64,000	
	Allowance for making good, additional structural support etc	1	item	5,000	5,000	
	BWIC with MEP Services	3	%		2,070	
	Testing & Commissioning	5	%		3,554	
	Subcontractor Preliminaries	12	%		8,955	
	Subtotal				**83,578**	
	Client Oncosts					
	Professional Fees	8	%		6,686	
	Client Risk/Contingency	10	%		9,026	
	VAT	20	%		19,858	
	Option Total				**119,149**	**Carry to summary**
6.9	**Provision of automatic lighting controls throughout**					
	New automatic lighting controls throughout	1,709	m2	15	25,635	Assumed to full GIFA
	BWIC with MEP Services	3	%		769	
	Testing & Commissioning	5	%		1,320	
	Subcontractor Preliminaries	12	%		3,327	
	Subtotal				**31,051**	
	Client Oncosts					
	Professional Fees	8	%		2,484	
	Client Risk/Contingency	10	%		3,354	
	VAT	20	%		7,378	
	Option Total				**44,267**	**Carry to summary**

Item	Description	Qty	Unit	Rate	Total (£)	Comments

Appendix B – Display Energy Certificates

Display energy certificate (DEC)

HM Government

DAVY BUILDING
University of Plymouth
Plymouth Main Campus
PLYMOUTH
PL4 8AA

Operational rating

D

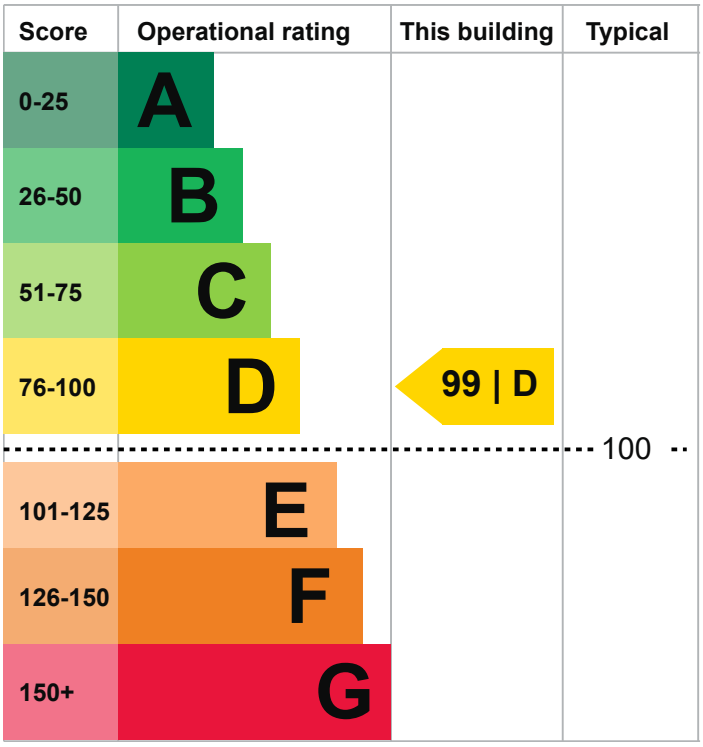
Certificate number:	2279-1752-7297-2798-7305
Valid until:	29 September 2022
Total useful floor area:	10086 square metres

Energy performance operational rating

The building's energy performance operational rating is based on its carbon dioxide (CO2) emissions for the last year.

It is given a score and an operational rating on a scale from A (lowest emissions) to G (highest emissions).

The typical score for a public building is 100. This typical score gives an operational rating of D.



This building's energy use

Energy use	Electricity	Other fuels
Annual energy use (kWh/m2/year)	91.70	185.82
Typical energy use (kWh/m2/year)	80	223.81
Energy from renewables	33.1%	12.2%

Previous operational ratings

Date	Operational rating
September 2021	99 | D
October 2020	120 | E
September 2019	97 | D

Total carbon dioxide (CO2) emissions

This tells you how much carbon dioxide the building emits. It shows tonnes per year of CO2.

Date	Electricity	Heating	Renewables
September 2021	509	364	315
October 2020	875	154	26
September 2019	623	211	0

Assessment details

Assessor's name	Alastair Humphries-Cuff
Employer/Trading name	Esos Energy
Employer/Trading address	5th Floor, Castlemead Tower, Lower, Bristol, BS1 3BN
Assessor's declaration	Contractor to the occupier for EPBD services only.
Accreditation scheme	CIBSE Certification Limited
Issue date	3 December 2021
Nominated date	30 September 2021

Display energy certificate (DEC)

HM Government

LINK BUILDING
University of Plymouth
Plymouth Main Campus
PLYMOUTH
PL4 8AA

Operational rating

C

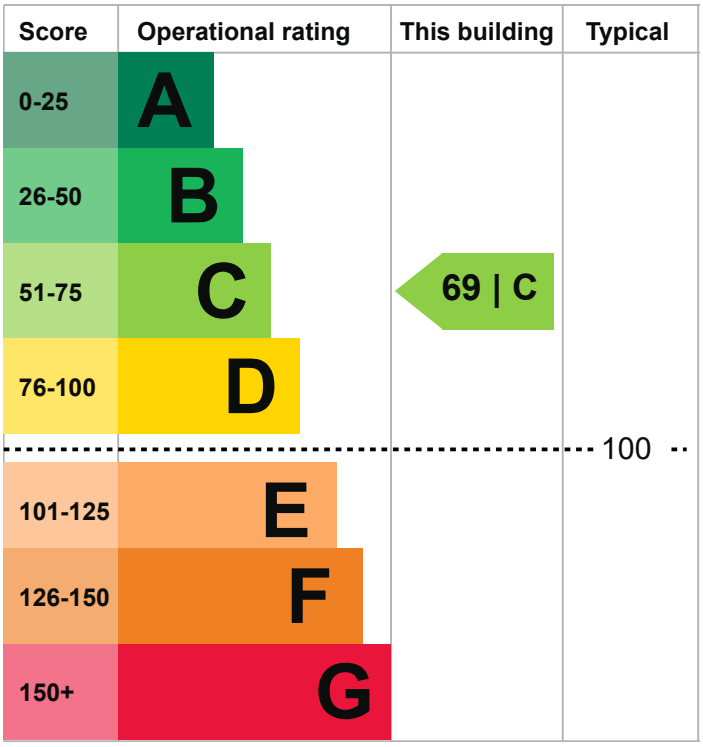
Certificate number:	9029-7266-8129-9736-2730
Valid until:	29 September 2022
Total useful floor area:	2384 square metres

Energy performance operational rating

The building's energy performance operational rating is based on its carbon dioxide (CO2) emissions for the last year.

It is given a score and an operational rating on a scale from A (lowest emissions) to G (highest emissions).

The typical score for a public building is 100. This typical score gives an operational rating of D.



This building's energy use

Energy use	Electricity	Other fuels
Annual energy use (kWh/m2/year)	48.84	185.82
Typical energy use (kWh/m2/year)	80	223.81
Energy from renewables	0%	12.2%

Previous operational ratings

Date	Operational rating
September 2021	69 | C
October 2020	50 | B
September 2019	58 | C

Total carbon dioxide (CO2) emissions

This tells you how much carbon dioxide the building emits. It shows tonnes per year of CO2.

Date	Electricity	Heating	Renewables
September 2021	64	80	13
October 2020	68	34	0
September 2019	78	40	0

Assessment details

Assessor's name	Alastair Humphries-Cuff
Employer/Trading name	Esos Energy
Employer/Trading address	5th Floor, Castlemead Tower, Lower, Bristol, BS1 3BN
Assessor's declaration	Contractor to the occupier for EPBD services only.
Accreditation scheme	CIBSE Certification Limited
Issue date	3 December 2021
Nominated date	30 September 2021

Display energy certificate (DEC)

HM Government

SMEATON BUILDING
University of Plymouth
Plymouth Main Campus
PLYMOUTH
PL4 8AA

Operational rating

E

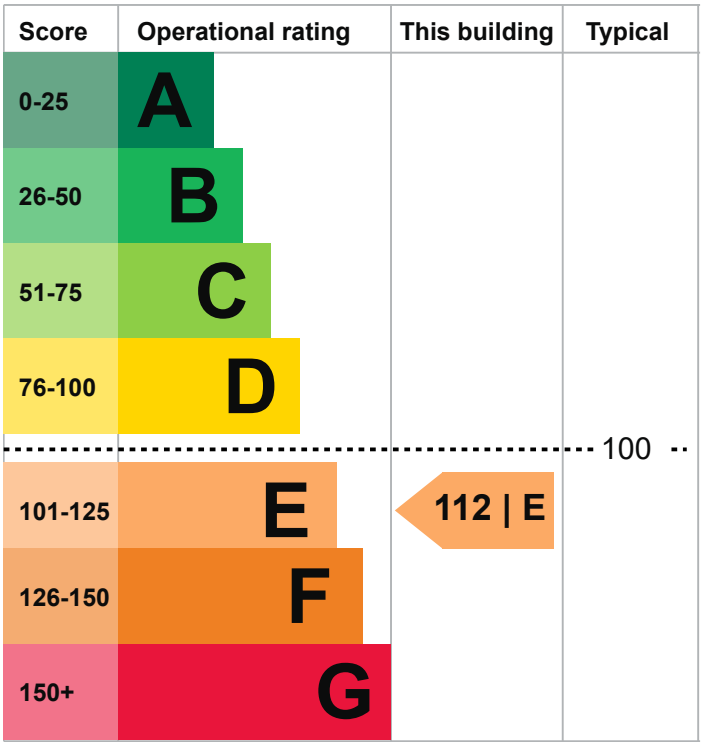
Certificate number:	1762-0019-4532-5802-6992
Valid until:	29 September 2022
Total useful floor area:	5232.99 square metres

Energy performance operational rating

The building's energy performance operational rating is based on its carbon dioxide (CO2) emissions for the last year.

It is given a score and an operational rating on a scale from A (lowest emissions) to G (highest emissions).

The typical score for a public building is 100. This typical score gives an operational rating of D.



This building's energy use

Energy use	Electricity	Other fuels
Annual energy use (kWh/m2/year)	131.57	185.82
Typical energy use (kWh/m2/year)	100.59	202.37
Energy from renewables	0%	12.2%

Previous operational ratings

Date	Operational rating
September 2021	112 | E
October 2020	86 | D
September 2019	100 | D

Total carbon dioxide (CO2) emissions

This tells you how much carbon dioxide the building emits. It shows tonnes per year of CO2.

Date	Electricity	Heating	Renewables
September 2021	379	175	30
October 2020	344	74	0
September 2019	376	105	1

Assessment details

Assessor's name	Alastair Humphries-Cuff
Employer/Trading name	Esos Energy
Employer/Trading address	5th Floor, Castlemead Tower, Lower, Bristol, BS1 3BN
Assessor's declaration	Contractor to the occupier for EPBD services only.
Accreditation scheme	CIBSE Certification Limited
Issue date	3 December 2021
Nominated date	30 September 2021

Display energy certificate (DEC)

HM Government

SCOTT BUILDING
University of Plymouth
Plymouth Main Campus
PLYMOUTH
PL4 8AA

Operational rating

C

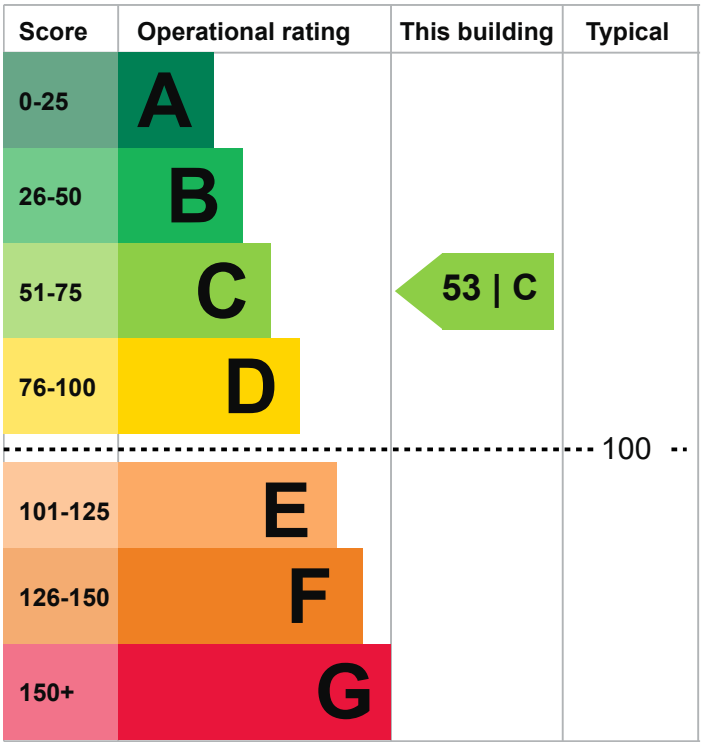
Certificate number:	8756-6819-8112-8302-8192
Valid until:	29 September 2022
Total useful floor area:	3651.53 square metres

Energy performance operational rating

The building's energy performance operational rating is based on its carbon dioxide (CO2) emissions for the last year.

It is given a score and an operational rating on a scale from A (lowest emissions) to G (highest emissions).

The typical score for a public building is 100. This typical score gives an operational rating of D.



This building's energy use

Energy use	Electricity	Other fuels
Annual energy use (kWh/m2/year)	57.42	58.79
Typical energy use (kWh/m2/year)	75.92	200.79
Energy from renewables	0%	0%

Previous operational ratings

Date	Operational rating
September 2021	53 | C
October 2020	49 | B
September 2019	61 | C

Total carbon dioxide (CO2) emissions

This tells you how much carbon dioxide the building emits. It shows tonnes per year of CO2.

Date	Electricity	Heating	Renewables
September 2021	115	42	0
October 2020	113	27	0
September 2019	142	33	0

Assessment details

Assessor's name	Alastair Humphries-Cuff
Employer/Trading name	Esos Energy
Employer/Trading address	5th Floor, Castlemead Tower, Lower, Bristol, BS1 3BN
Assessor's declaration	Contractor to the occupier for EPBD services only.
Accreditation scheme	CIBSE Certification Limited
Issue date	3 December 2021
Nominated date	30 September 2021

Display energy certificate (DEC)

HM Government

MARINE BUILDING
University of Plymouth
Drake Circus
PLYMOUTH
PL4 8AA

Operational rating

C

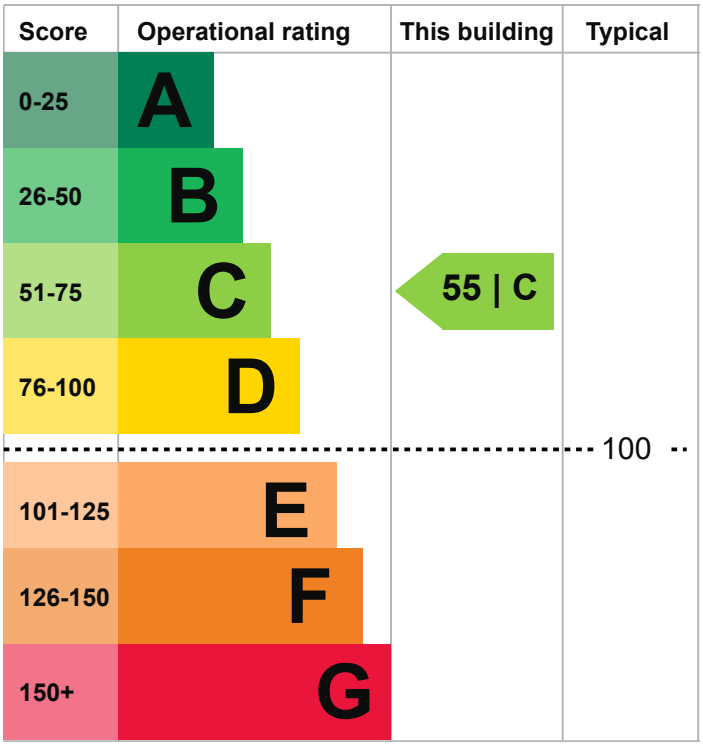
Certificate number:	2379-1052-9696-7892-7405
Valid until:	29 September 2022
Total useful floor area:	4165.20 square metres

Energy performance operational rating

The building's energy performance operational rating is based on its carbon dioxide (CO2) emissions for the last year.

It is given a score and an operational rating on a scale from A (lowest emissions) to G (highest emissions).

The typical score for a public building is 100. This typical score gives an operational rating of D.



This building's energy use

Energy use	Electricity	Other fuels
Annual energy use (kWh/m2/year)	79.50	112.16
Typical energy use (kWh/m2/year)	111.20	293.60
Energy from renewables	0%	18.7%

Previous operational ratings

Date	Operational rating
September 2021	55 | C
October 2020	48 | B
September 2019	73 | C

Total carbon dioxide (CO2) emissions

This tells you how much carbon dioxide the building emits. It shows tonnes per year of CO2.

Date	Electricity	Heating	Renewables
September 2021	182	91	26
October 2020	188	42	0
September 2019	276	73	0

Assessment details

Assessor's name	Alastair Humphries-Cuff
Employer/Trading name	Esos Energy
Employer/Trading address	5th Floor, Castlemead Tower, Lower, Bristol, BS1 3BN
Assessor's declaration	Contractor to the occupier for EPBD services only.
Accreditation scheme	CIBSE Certification Limited
Issue date	3 December 2021
Nominated date	30 September 2021

Display energy certificate (DEC)

HM Government

THE HOUSE
University of Plymouth
Plymouth Main Campus
PLYMOUTH
PL4 8AA

Operational rating

B

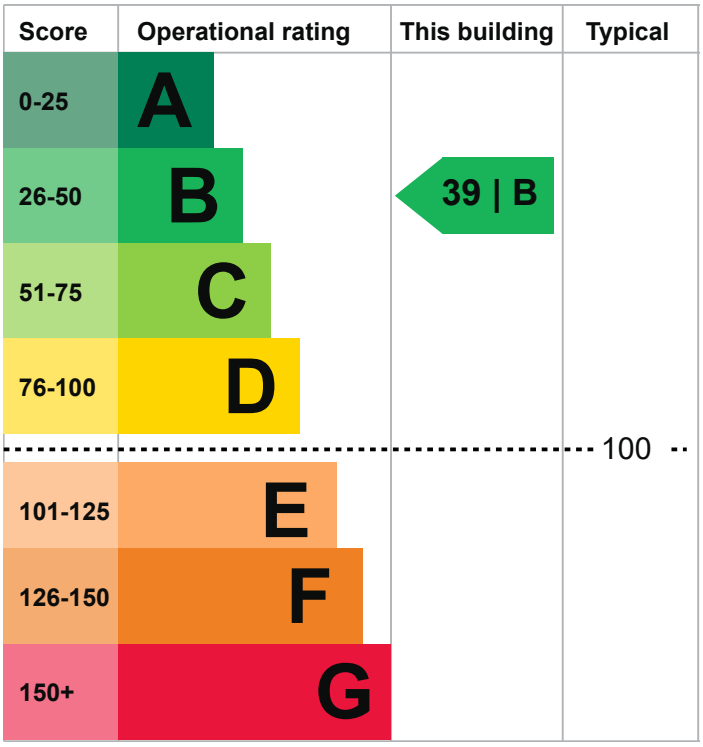
Certificate number:	0776-1419-4362-1902-0596
Valid until:	29 September 2022
Total useful floor area:	1708.60 square metres

Energy performance operational rating

The building's energy performance operational rating is based on its carbon dioxide (CO2) emissions for the last year.

It is given a score and an operational rating on a scale from A (lowest emissions) to G (highest emissions).

The typical score for a public building is 100. This typical score gives an operational rating of D.



This building's energy use

Energy use	Electricity	Other fuels
Annual energy use (kWh/m2/year)	32.27	111.53
Typical energy use (kWh/m2/year)	95.02	251.26
Energy from renewables	0%	18.8%

Previous operational ratings

Date	Operational rating
September 2021	39 | B
October 2020	42 | B
September 2019	45 | B

Total carbon dioxide (CO2) emissions

This tells you how much carbon dioxide the building emits. It shows tonnes per year of CO2.

Date	Electricity	Heating	Renewables
September 2021	30	37	10
October 2020	44	26	0
September 2019	46	30	0

Assessment details

Assessor's name	Alastair Humphries-Cuff
Employer/Trading name	Esos Energy
Employer/Trading address	5th Floor, Castlemead Tower, Lower, Bristol, BS1 3BN
Assessor's declaration	Contractor to the occupier for EPBD services only.
Accreditation scheme	CIBSE Certification Limited
Issue date	3 December 2021
Nominated date	30 September 2021

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