



Energy Efficiency Analysis of a Small NHS Clinical Building in South Wales

Author's Declaration

I declare that the work in this dissertation was carried out in accordance with the regulations of UWTSD. The work is original except where indicated by special references in the text and no part of the dissertation has been submitted for any other degree.

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Signed:

Date: 07.03.2026

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Abstract

Considering NHS decarbonisation goals, to protect public health, this study assesses the technical and financial viability of installing an Air Source Heat Pump (ASHP) in place of the current gas-fired heating system in a small clinical building in South Wales. The building's heating demand was calculated using two quantitative methods: a room-by-room heat loss calculation based on CIBSE guidelines, and a thorough energy model created using the Passive House Planning Package (PHPP). Both approaches showed considerable inefficiencies in the thermal envelope, ventilation plan, and building fabric; PHPP modelling showed high yearly heat losses caused by inadequate airtightness, little solar gain, and large distribution losses. To determine baseline operational performance and costs, actual gas and electricity usage data from April 2024 to March 2025 were studied.

Three 10kW units made up a fictional ASHP system that was sized to match the building's peak heating load and calculated to determine how it would affect energy use and operating expenses. The findings show that although demand for electricity would rise, gas use could be cut by roughly 64%. This would result in an estimated £5,138 in annual savings and a six-year return on investment. The results emphasise the necessity for additional fabric changes to enhance efficiency, highlighting both the potential and the constraints of ASHP implementation in older, thermally inefficient healthcare buildings. In addition to identifying opportunities for additional optimisation through improved insulation, upgraded glazing, and mechanical ventilation with heat recovery, the study offers evidence to guide decarbonisation plans across similar NHS estate typologies.

Glossary

ACH – Air Changes per Hour

AHU – Air Handling Unit

ASHP – Air Source Heat Pump

BEM – Building Energy Modelling

BMS – Building Management System

CAFM – Computer Aided Facilities Management

COP – Coefficient of Performance

CO₂ – Carbon Dioxide

CHP – Combined Heat and Power

DHW – Domestic Hot Water

EEF – Energy Efficient Fund

GHG – Green House Gases

GSHP – Ground Source Heat Pump

GWP – Global Warming Potential

HFC – Hydrofluorocarbon

HVAC – Heating Ventilation and Air Conditioning

LED – Light Emitting Diode

LPHW – Low Pressure Hot Water

LTHW – Low Temperature Hot Water

MVHR – Mechanical Ventilation Heat Recovery

NDRHI – Non-Domestic Renewable Heat Incentive

NHS – National Health Service

PER – Primary Energy Renewable

PHPP – Passive House Planning Package

SCOP – Seasonal Coefficient of Performance

SPF – Seasonal Performance Factor

TFA – Treated Floor Area

UKCS – United Kingdom Continental Shelf

UNFCCC – United Nations Framework Convention on Climate Change

WSHP – Water Source Heat Pump

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1.0 Introduction

1.1 Background

Green House Gases (GHG) help retain solar heat, making Earth suitable for human life and countless other species. However, their current imbalance poses serious risks to the survival and distribution of life on the planet. Anthropogenic emissions from fossil fuel combustion have significantly increased atmospheric concentrations of GHG. These gases capture solar radiation and inhibit heat dissipation into space, a phenomenon referred to as the GHG effect (Nunez, 2019). GHG released into the atmosphere include carbon dioxide, as the most prevalent, methane, nitrous oxide, and smaller amounts of gases like hydrofluorocarbons and sulphur hexafluoride (Londoño-Pulgarin *et al.*, 2021). The multifaceted transformations in atmospheric and ecological systems, primarily driven by these increased GHG concentrations refers to the term 'climate change'. It encompasses global temperature rise, intensified weather extremes, where periods of heat and drought may intensify airborne dust, strain water supply and quality, and drive-up demand for both emergency utilities and response services, altered species distributions, sea level escalation, and numerous other consequences (Nunez, 2019, Short *et al.*, 2015). Regarding healthcare specifically, shifts in environmental conditions are projected to facilitate the wider transmission of infectious diseases, heightening the risk of additional pandemic outbreaks (Syed *et al.*, 2022).

The UK has a legally enforceable goal to attain net-zero GHG emissions by 2050, making it the first major economy in the world to do so. To help achieve this, a goal was set in April 2021 to cut emissions by 78% by the year 2035 (Department for Business, Energy & Industrial Strategy, 2021). Buildings are responsible for contributing around 30% of the nation's GHG emissions through heat production and a third of the UK's energy usage (Harris and Walker, 2023, Department for Business, Energy & Industrial Strategy, 2021). With over 80% of buildings receiving their heat from gas boilers, Britain's heavy reliance on natural gas makes decarbonising the heat sector a significant task (Ehsan and Preece, 2022). By aiming to cut GHG emissions from public sector buildings in half by 2023, the government wanted to set the standard by decarbonising its buildings (Department for Business, Energy & Industrial Strategy, 2021).

With this, the National Health Service (NHS) formally committed to achieving the net-zero target by 2040. The healthcare sector accounts for between 4-5% of carbon emissions (Sandoval *et al.*, 2023 & Hawkins, 2022), for example, 25 mega tonnes of carbon dioxide (CO₂) were released into the atmosphere by the NHS in 2019 (Booth, 2022) with around 20% of this coming from buildings (Fifield *et al.*, 2018). The ability of health services to deliver high-quality care is currently in jeopardy due to climate change (Tennison *et al.*, 2021). Heatwaves have already caused more deaths in England and can put extra pressure on hospitals, care services, and essential infrastructure like water, energy, and transport. They can also lead to problems like poor air quality and crop damage, which affect people's health. Warmer weather makes it easier for certain diseases to spread, and the UK may face more cases of new infections. In addition, climate-driven weather extremes in supplier nations can disrupt food availability and safety, while global impacts may lead to higher migration to the UK (Gillingham *et al.*, 2023). Furthermore, Powlesland and Joyce (2021) predict that by 2030, climate change will result in an extra 250,000 deaths globally.

1.2 Aim

Given the current financial pressures on the NHS, money saving strategies are being trialled throughout the UK, therefore, with this in mind, the aim of this project is to evaluate the technical and financial feasibility of replacing the existing gas boiler system with an Air Source Heat Pump (ASHP) in a small clinical building within a large health board in South Wales, with the goal of identifying opportunities to reduce operational costs and carbon emissions.

1.3 Objectives

To address the aim, this research will consider the following objectives.

1. To comprehend the forces behind the decarbonisation of heating systems in the NHS and in society at large, and to determine how the NHS is reacting with its existing policies and programs

2. Determine whether the building is suitable for an ASHP by evaluating its current infrastructure and thermal profile. Then, create a concept design for the proposed ASHP installation that considers the building's operational needs, heating demand, and space limitations
3. Examine installation and running costs in relation to the existing gas boiler configuration, considering possible cost savings.
4. Ascertain whether the results can guide more comprehensive decarbonisation plans for comparable NHS assets

1.4 Project Structure

The next section will provide a comprehensive literature review of climate change and the impact of building services on climate change such as electricity, heating, fossil fuels, and building fabric. The literature review will also cover the impact of the NHS on climate change, and decarbonisation strategies and plans that have been produced by the NHS to combat climate change. Research will then further into heat pumps, and their benefits and challenges. Section 3 provides details on the methodology used to achieve the aim and objectives. Section 4 presents an in-depth analysis of the results from both methods, where Section 5 concludes the project, with recommendations and further research noted.

2.0 Literature Review

2.1 Climate Change

Short *et al.* (2015) believe that the greatest threat to global health this century is climate change, with increasing global temperatures having already inflicted serious harm on human habitats, leading to species extinction, declining biodiversity, extreme droughts, severe floods, widespread wildfires, ocean acidification, melting glaciers at both poles, and rising sea levels (Chen *et al.*, 2022). These impacts have the potential to cause lasting harm to the Earth's life-supporting systems, posing a serious risk to human health (Dasandi *et al.*, 2021).

A primary driving factor for climate change is GHG emissions, where heat is trapped within the Earth's atmosphere. A 2% rise in global GHG and CO₂ emissions was recorded in 2018, exceeding the average annual growth rate of 1.5% observed over the previous ten years. This increase in CO₂ emissions in 2018 was largely attributed to a surge in energy consumption (Fawzy *et al.*, 2020). Atmospheric CO₂ levels have reached unprecedented heights, with Syed *et al.* (2022) indicating that current concentrations are now 50% above pre-industrial levels. The first formal acknowledgement of the challenges posed by climate change is widely traced to the 1979 World Climate Conference in Geneva (Fawzy *et al.*, 2020), however, with the impact rising, on December 12, 2015, all 197 parties to the United Nations Framework Convention on Climate Change (UNFCCC) reached a unanimous decision at the Paris Climate Conference to adopt the Paris Agreement, a global framework outlining climate action strategies for the post-2020 era (Chen *et al.*, 2022). Following this, in 2019, the UK Climate Change Act 2008 was amended to establish a target of achieving net zero emissions by 2050 (Slorach and Stamford, 2021). Subsequently, as of February 2021, 124 nations had formally committed to reaching carbon neutrality by either 2050 or 2060 (Chen *et al.*, 2022).

Achieving net-zero involves equalising the amount of CO₂ or other GHG emitted with the amount removed or offset, across all sources and activities within a defined period. Around 60.6% of nations, or 120 out of 198, have committed to achieving this by 2050–2070. Among the 198 nations pursuing Net Zero, 4.5% have reached the goal, 10.6% have issued formal commitments, 8.6% have legislated for it, 29.3% have introduced policy frameworks, and 47% are actively engaged in preparatory discussions. Further to this, Figure 1 shows the status of all countries net-zero targets. There are a few countries in South America and Africa that have self-declared net-zero emissions, with many countries having laws on targets, which includes the UK, America and Australia. However, most of the world's countries only have policies in place.

Status of net-zero carbon emissions targets

The inclusion criteria for net-zero commitments may vary from country to country. For example, the inclusion of international aviation emissions; or the acceptance of carbon offsets. To see the year for which countries have pledged to achieve net-zero, hover over the country in the interactive version of this chart.

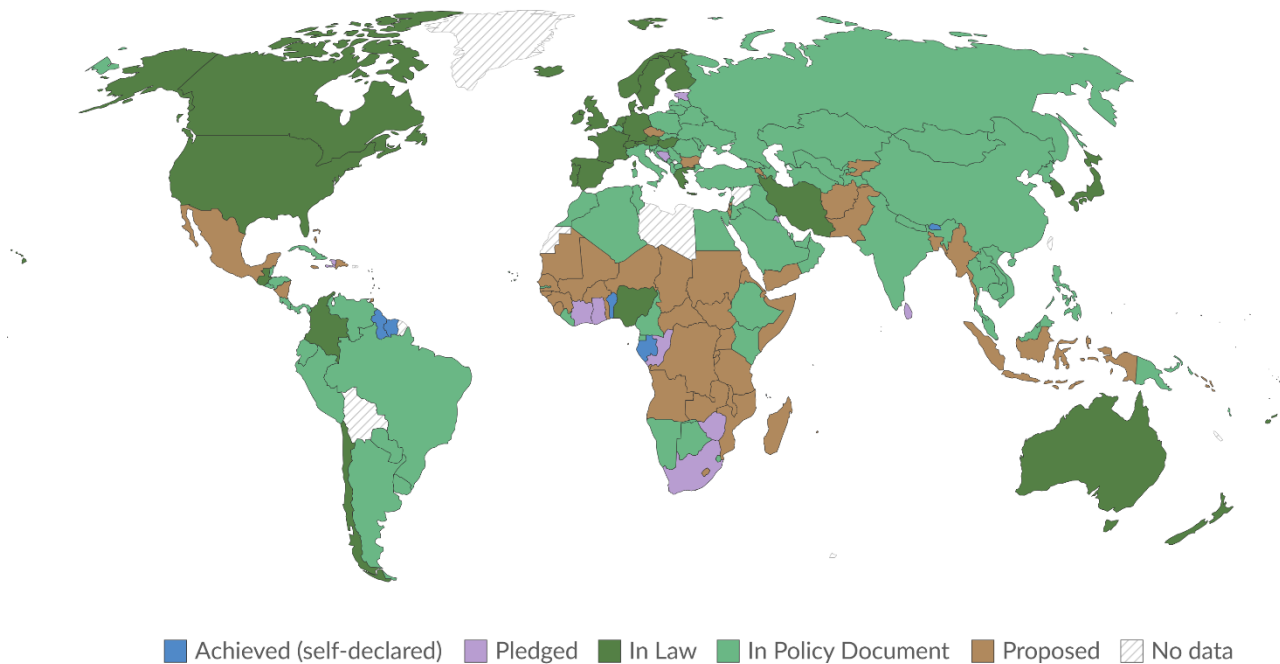


Figure 1 - Status of net-zero carbon emissions targets (Energy and Climate Intelligence Unit, 2023)

Global atmospheric CO₂ concentrations rose sharply from 285 ppm in 1850 to 419 ppm in 2022, accompanied by an estimated global surface temperature increase of 0.97–1.21 °C over the same period (Chen *et al.*, 2022). According to Fawzy *et al.* (2020), achieving the 1.5°C climate goal requires global emissions to be restricted to 25–30 Gt CO₂ emissions per year by 2030, putting further pressure on countries to decarbonise. By 2035, the UK aims to cut emissions by 78% compared with 1990 levels—equivalent to a 63% reduction from 2019. Building-related direct emissions fell by 19% between 1990 and 2015 but have since plateaued, with the sector producing 87Mt CO₂e in 2019 and accounting for 17% of national emissions (Climate Change Committee, 2020).

There is little research on how energy systems and technologies are affected by climate change (Congedo *et al.*, 2022), with Sandoval *et al.* (2023) believing that one of the primary difficulties is persuading decision-makers, however, to achieve the legally mandated net-zero goal by 2050, the UK government has recognised that more than 30 million residential and commercial properties must be decarbonised within the next 25 years (Lee, 2023). Additionally, when policies change suddenly, they tend to carry major economic repercussions (Sandoval *et al.*, 2023). Furthermore, due to the economic fallout and financial volatility triggered by the COVID-19 pandemic, the likelihood of achieving the new European climate objectives is currently unclear (Möst *et al.*, 2021, pp. 10). In addition, Syed *et al.* (2022) have stated that geopolitical instability and ideological divergence continue to hinder the implementation of sustainable initiatives, threatening gains achieved to date.

There's growing debate over how climate change might alter summer indoor temperatures in UK buildings, since future summers are expected to be hotter, drier, and punctuated by more extreme heat events (Lomas and Giridharan, 2012). Presently, people have faced 1.4 extra days of heatwaves each year, on average, between 2000 and 2017, with 2,556 heatwave-related deaths occurring in England in 2020, a sharp rise from 892 fatalities in 2019. Further to this, extreme flooding accounts for approximately 15% of fatalities linked to natural disasters, a proportion likely to increase, with forecasts indicating up to 1.4 billion droughts and 2 billion flood events each year. Average temperatures in the UK have consistently increased by approximately 0.25°C every decade since the 1960s. Compared to the 1961–1990 baseline, annual mean temperatures are

expected to increase by 2.5°C to 4.2°C by 2080 (Short *et al.*, 2015). Additionally, over the last seven years, global temperatures have consistently exceeded historical records, averaging 1.2°C warmer than the pre-industrial baseline of 1850–1900 (Syed *et al.*, 2022).

2.1.1 Impact of Building Services on Climate Change

Building services refer to the integrated systems within a structure that ensure its comfort, functionality, energy efficiency, and safety. This may include lighting, Heating Ventilation and Air Conditioning (HVAC), plumbing, lifts and security systems (Designing Buildings, 2024). UK hospital buildings present unique and complex challenges in terms of both adapting to and mitigating climate change impacts (Lomas & Giridharan, 2011).

Building construction and operational activities account for nearly 50% of total energy consumption across the EU (Odineca *et al.*, 2019), whilst the use of buildings account for 40% of overall energy consumption and end-use carbon dioxide emissions (Carroll, Chesser and Lyons, 2020), with large-scale buildings contributing disproportionately to overall carbon emissions (Department for Business, Energy & Industrial Strategy, 2021). In 2004, buildings were responsible for releasing 8.6 billion metric tonnes of carbon dioxide equivalent (CO₂e) into the atmosphere (Sizirici *et al.*, 2021). If current trends persist, heating and cooling needs in buildings are set to grow nearly 80% by 2050 (Ding *et al.*, 2021).

The UK has the lowest building energy efficiency standards among European nations (Harris and Walker, 2023). Therefore, enhancing building performance is essential for minimising energy losses and integrating efficient systems alongside renewable energy technologies (Danza *et al.*, 2016) with reducing carbon emissions from buildings being a key factor in achieving the carbon budget and reaching net-zero targets (Department for Business, Energy & Industrial Strategy, 2021, Norouzi *et al.*, 2023). Given the focus on energy efficiency, buildings should be designed to minimise carbon emissions and environmental impact, while also operating efficiently, effectively, and reliably in response to anticipated changes in external conditions—particularly those driven by climate change (Short *et al.*, 2015).

2.1.1.1 Electricity

Electrification presents the most practical route to reducing carbon emissions according to the Department for Business, Energy & Industrial Strategy (2021). However, this is likely to cause a sharp rise in electricity demand, placing added pressure on the grid (Ehsan and Preece, 2022). As of May 2023, the UK had generated one trillion kilowatt-hours of electricity from renewable sources (Lee, 2023)

Of the many approaches to sustainable retrofitting, electrification is especially significant. It entails substituting fossil fuel-based systems with electric alternatives during final energy use, which is particularly urgent for older buildings (Kim *et al.*, 2024). The decline in coal-based power and the growth of renewables, now accounting for about a third of UK electricity use, have led to a 45% drop in carbon intensity since 2012 (Howard and Gowdy, 2020, pp. 7). Figure 2 further supports this, with bioenergy, solar, wind and hydropower leading the way across the world in electricity production, with a clear previous domination from coal, oil and gas.

Electricity production by source, World

Measured in terawatt-hours¹.

Our World
in Data

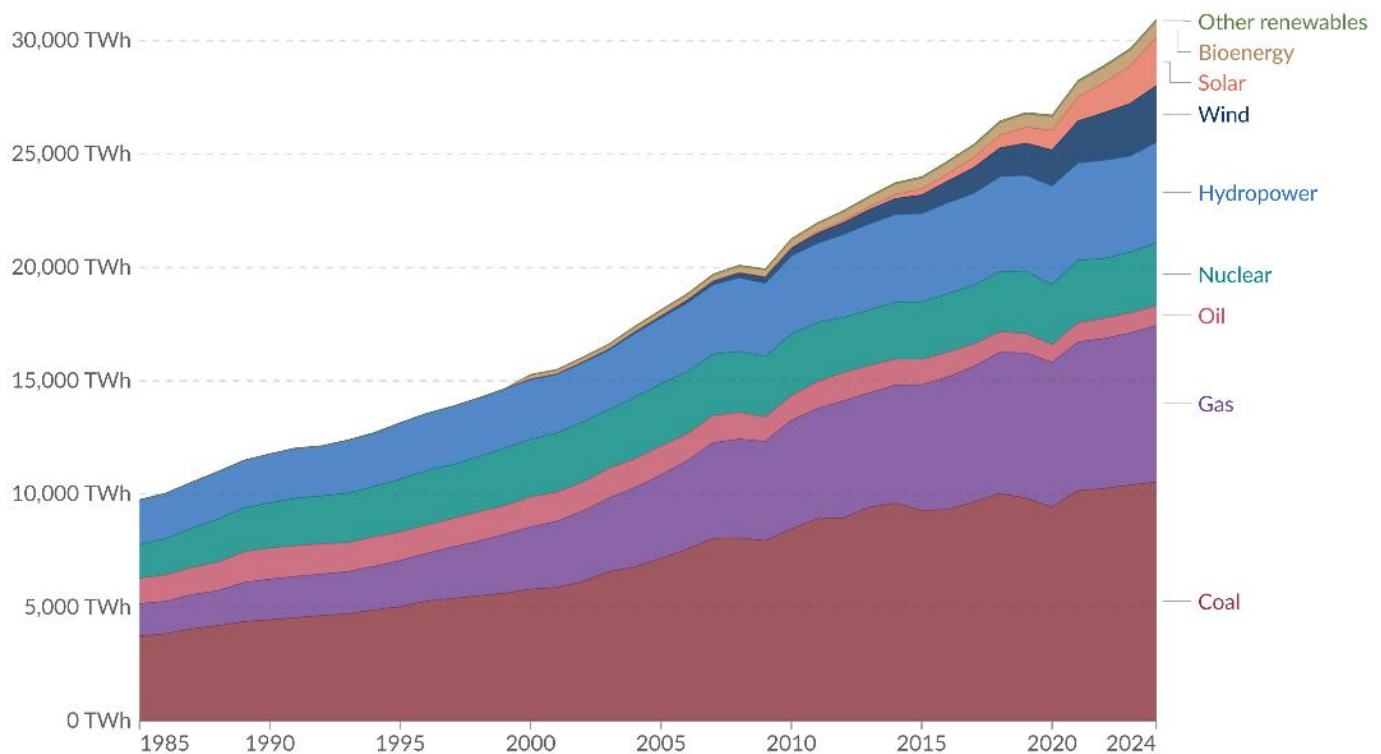


Figure 2 - Electricity Generation Worldwide (Energy Institute, 2025)

Rising costs of electricity are becoming an issue, with yearly electricity consumption and energy usage potentially steadily rising by 25 to 50 percent (Sandoval *et al.*, 2023, Congedo *et al.*, 2022, Harris and Walker, 2023, pp. 10). Conversely, electricity use has dropped by 14% since 2005 according to the Climate Change Committee (2020). In addition, it is believed that the yearly energy consumption for space and water heating in residential and commercial buildings would exceed the total electricity generated in the UK by 57%, with heating capacity peaking in January (Wang *et al.*, 2019, Slorach and Stamford, 2021, Harris and Walker, 2023). Further to this, Kimpton, Zhang and Stulz (2020) believe that meeting the heating demand with electricity would necessitate more than a twofold increase in the UK's electricity generation capacity, with a substantial portion of this additional output required primarily during the winter months.

2.1.1.2 Heating

Natural gas currently provides approximately three-quarters of the heat used in domestic and non-domestic buildings in the UK, with imports into the UK growing considerably, with supply routes including European pipelines and liquefied natural gas shipments—mainly originating from the Middle East. With an extensive network comprising nearly 7,500 km of transmission and 280,000 km of distribution pipelines, the UK delivers over 600 TWh of accessible fuel energy annually to 21.5 million consumers. It is believed that efficient gas-fired boiler systems provide a relatively low-cost solution for heating and hot water, with reduced emissions and cleaner air than coal or oil-based alternatives (Howard and Gowdy, 2020), however with GHG emissions rising, further insight into decarbonised technologies is required.

Decarbonising the heating sector will be crucial to achieving the legally enforceable carbon reduction targets, with a large proportion of the heating sector not currently being electric. Half of the total final energy consumption is dedicated to everyday heating needs (Sandoval *et al.*, 2023 & Sezen, 2023), where Naumann, Schropp and Gadarer (2022) state that heating demand is distributed as follows: 70% for space heating and 14% for domestic hot water supply, with the remaining share on other heat.

The global heating technology landscape has remained largely unchanged over the past decade, with fossil fuel-powered systems and electric heaters comprising nearly 80% of sales in 2019 (Slorach and Stamford,

2021). It is becoming more widely acknowledged that heat will present unique difficulties (MacLean *et al.*, 2016), with Burns and Strachan (2021) stating that decarbonising heating systems in both domestic and non-domestic buildings presents one of the greatest challenges. With this, there is currently no formal strategy in place to achieve net zero heating by 2050 (Slorach and Stamford, 2021). In November 2011, the Non-Domestic Renewable Heat Incentive (NDRHI) was introduced to provide financial backing for the deployment of approved renewable heating technologies in non-residential settings, however, the government scheduled the closure of the NDRHI scheme to new applicants effective from the 31st of March 2021, due to budgetary constraints and maturity of the renewable heat market, however, the closing date was forced to be extended due to the COVID-19 pandemic, which subsequently gave further opportunities to apply (Department for Business, Energy & Industrial Strategy, 2021).

With fossil fuels still providing about 90% of district heat worldwide and even larger shares in the two biggest markets, China and Russia, the decarbonisation potential of district heating is currently mostly unrealised (Acke *et al.*, 2022). As of 2014, only 4.8% of the UK's heat supply came from renewable or low-carbon sources—the lowest proportion in the EU (MacLean *et al.*, 2016). Additionally, at present, just 7% of heat networks in the UK utilise low-carbon heat sources (Howard and Gowdy, 2020). However, the significant impact of the heating sector on global emissions has elevated the decarbonisation of heat as a key area of focus for researchers and policy makers alike. With this, in 2019, heating in buildings across Great Britain was estimated to account for 17% of the nation's GHG emissions, with approximately 4Gt CO₂ emissions globally from space heating and hot water generation, and heating-related emissions making up a substantial share of human-caused environmental pollution (Ehsan and Preece, 2022, Acke *et al.*, 2022, Naumann, Schropp and Gadarer, 2022). In addition, Sandoval *et al.* (2023) have stated that heating contributes to more than one-third of total GHG emissions. Efforts to reduce carbon emissions from heating have been widely criticised for not advancing quickly enough by the Parliament Offices of Science & Technology (2016). Heat emissions are predominantly generated by the domestic sector (50%), with the industrial and commercial sectors contributing 30% and 20% respectively (Parliament Offices of Science & Technology, 2016).

2.1.1.3 Fossil Fuels

Industries are heavily reliant on fossil fuels, such as coal, natural gas and oil for industrial processes. Fossil fuels became central to energy production following the industrial revolution's expansion (Londoño-Pulgarin *et al.*, 2021). When burnt, CO₂ is released into that atmosphere, causing damage to the earth's climate. Eliminating fossil fuel-based energy generation would help limit global temperature increase to below 2°C (Sandoval *et al.*, 2023). GHG emissions are projected to increase by half by 2050, mainly due to carbon dioxide released from the continued use of fossil fuels, where the ongoing reliance on fossil fuels led to a record-high level of carbon dioxide emissions in 2020, playing a major role in accelerating global warming (Chen *et al.*, 2022).

Gas combustion is estimated to contribute 18% of the UK's total GHG emissions, where gas boilers contribute more to climate change than any of the emerging heating technologies (Slorach and Stamford, 2021). Seventy-five percent of heating energy comes from burning fossil fuels, mainly natural gas (Harris and Walker, 2023), where natural gas supplies 57% of the heating demand for buildings across Europe (Slorach and Stamford, 2021), and overall, the UK's gas network presently serves approximately 80% of buildings nationwide. In addition, over 70% of heat energy across domestic, industrial, and service sectors is still generated by burning natural gas (OFGEM, 2016). The UK's evolved natural gas infrastructure plays a uniquely versatile role in the broader energy landscape, enabling energy delivery, fuel transport and storage, and supporting the system's ability to handle peak heating demands. It also spans the country and offers a pathway to integrate supply across electricity, heating, and transport (MacLean *et al.*, 2016). The UK reached its highest natural gas output in 2000, exceeding 1,260 TWh, with most supply originating from United Kingdom Continental Shelf (UKCS) fields in the North and Irish Sea, however, a downward trend in gas consumption has been observed since 2004 (Howard and Gowdy, 2020), however, natural gas output has experienced consistent growth, increasing from 1.104¹² m³ in 2005 to 1.304¹² m³ in 2015 (Londoño-Pulgarin *et al.*, 2021).

Sandoval *et al.* (2023) and Altermatt *et al.* (2023) believe that minimizing fossil fuel consumption to achieve net-zero goals, alongside enhancing the efficiency of energy conversion systems is essential, however this

will only occur following a policy change or intervention, and natural gas will continue to be a cost-effective option unless carbon emission costs rise significantly (Slorach and Stamford, 2021). In addition, the reliability of gas supplies has been destabilised abruptly due to the recent Russo-Ukrainian War (Altermatt *et al.*, 2023). Fossil fuels supply 90% of energy demands and contribute to 40% of global carbon dioxide emissions (Slorach and Stamford, 2021). According to Londoño-Pulgarin *et al.* (2021), the shift toward renewable energy is shaped by four major global forces: fossil fuel exhaustion, escalating costs from limited resources, the urgent need to address GHG emissions, and the rise of environmentally conscious consumer behaviour. Chen *et al.* (2022) believe that the use of fossil fuels must be swiftly reduced, with strong backing given to the development and deployment of clean energy technologies and shifting from fossil fuels to renewable energy is essential for achieving carbon neutrality in the future.

2.1.1.4 Building Fabric

ARUP (2020) believe that regardless of building typology, effective insulation and airtightness are key to reducing external heat loss. It is recommended, that when designing a net zero healthcare building, that there are three insulated sub-basement levels, given the scope to reduce solar gain and thermal fluctuations, that incorporates preventing moisture build up, is fire rated, and efficient, while offering substantial thermal mass to passively regulate indoor conditions. A further factor to consider is the building fabric's U-value, which represents the rate of heat flow through a building element, where lower values signify less thermal transmission. Highly efficient building materials should be considered when constructing a building, and a low U-value should be sought-after for external and internal walls, roofs, floors, doors and windows to ensure low heat loss is at a minimum.

2.1.2 NHS Impact

The NHS estate comprises 217 individual trusts, each implementing its own 'green plan' across a total of 1,228 hospitals (Orton, 2023). As the largest employer in Europe, the NHS holds significant influence and is well positioned to lead efforts in reducing emissions across the sector (Tennison *et al.*, 2021). By 2032, the government wants to cut emissions from the public sector by 50% compared to 2017 (Climate Change Committee, 2020). However, the NHS has been a big contributor to GHG, where in 2015, accounted for 4.5% of the United Kingdom's total emissions (Fifield *et al.*, 2018). From this, climate change has posed a growing risk to the capacity of the health system to consistently provide high-quality care (Tennison *et al.*, 2021).

When it comes to electricity, water, and other resources, hospitals and healthcare facilities are among the most resource-intensive structures. Every facility presents unique specifications for access, environmental control, humidity, hygiene, air filtration, and connectivity to water, power, and hospital-wide communications (ARUP, 2021). Due to the complexity of hospital requirements, energy performance is often not a primary focus for designers and stakeholders (Chiang *et al.*, 2017). Specialised zones within healthcare buildings demand intensive ventilation strategies to support infection control measures (ARUP, 2020). The NHS continues to be the UK's highest contributor to carbon emissions (James Paget University Hospital, 2021). As of 2007, NHS England's operations generated 21 million tonnes of CO₂ emissions, whereas, as of 2012, NHS operations in England generated 32 million tonnes of CO₂e, equivalent to 40% of the public sector's carbon output. Further to this, the NHS was responsible for emitting 24.9 million tonnes of CO₂ in the year 2020 (Syed *et al.*, 2022). A large increase in CO₂ emissions over a short period has been observed, with patient demands rising and infrastructure expanding to meet these demands. Without intervention, the NHS's environmental footprint was expected to surge by 55% (NHS Sustainable Development Unit, 2010, Short *et al.*, 2015). Nevertheless, the healthcare sector prioritises human health outcomes, often placing limited focus on environmental considerations (Duindam, 2022).

Achieving the UK's GHG targets depends heavily on the NHS, Department of Health, and the trusts that operate our healthcare services, however in the UK, hospitals present particularly demanding requirements for both adapting to and reducing the impacts of climate change (Lomas and Giridharan, 2011). Widespread maintenance needs, legacy buildings, and financial constraints across the healthcare estate pose significant barriers to implementing emission-reducing upgrades (ARUP, 2020). Carbon footprint evaluations of healthcare systems have been conducted in relatively few nations (Booth, 2022), however, the government plans to cut public sector emissions by half by 2032, using 2017 levels as the baseline (Climate Change Committee, 2020).

Hot water and space heating systems are responsible for 80% of the NHS's total GHG emissions (Flood, 2022), equating to approximately 22% of the UK's total carbon footprint (Rook, 2023). In addition, air and space heating account for 44% of the energy consumption in a typical UK NHS hospital (Fifield *et al.*, 2018). As of April 2022, annual heating-related gas consumption across the trusts averaged 55 GWh, with Weston General Hospital contributing roughly 11% (Energy Managers Association, 2023).

A recommendation by Fifield *et al.* (2018) to upgrading all NHS buildings would potentially cut energy consumption by 25%, however due to cost implications, this could be unrealistic. However, according to Booth, in 2019, the NHS had reduced its emissions by 26% compared to levels in 1990. Upgrading the energy performance of NHS buildings contributes to the broader initiative and enables compliance with the target of a 34% carbon reduction relative to 1990 benchmarks by 2020 (Short *et al.*, 2015).

With an outlook on how NHS trusts are performing, between 2007 and 2019, Norfolk and Norwich University Hospitals Trust (2021) experienced a marked increase driven by key operational changes: a 2% expansion in internal floor area, a 66% rise in staffing, and a 77% surge in patient activity. With this, during 2020/21, operational emissions from Bolton NHS Foundation Trust (2022) totalled 11,647 tonnes of CO₂ emissions, comparable to the yearly energy consumption of over 2,329 households. Hospital infrastructure drives the bulk of Manchester University NHS Trusts (2021) emissions, accounting for 83% of the trusts core carbon footprint and 17% of the broader footprint. St Mary's Hospital, Isle of Wight's main trust facility, consumed over 6,000,000 kWh of electricity and 17,000,000 kWh of gas in 2020/21, resulting in emissions of 5,588 tonnes CO₂ emissions (Ritcher, 2021). In Wales, 2021/22 emissions stood at 202,000 tonnes CO₂ emissions for Cardiff and Vale University Health Board (2023).

2.2 NHS Trusts Decarbonisation Plans and Strategies

With a focus turned towards reducing carbon emissions within the NHS, launched in 2020, the Greener NHS initiative committed NHS England to reaching net zero carbon emissions by 2040—setting a global benchmark for healthcare decarbonisation (Bloomfield *et al.*, 2021). Supporting this, the NHS has actively measured and monitored its GHG output for around a decade prior, to find excessive emissions (Tennison *et al.*, 2021). It is predicted that lowering carbon output across NHS operations has the potential to generate cost savings exceeding £180 million annually (NHS Sustainable Development Unit, 2010).

Challenges of refurbishing NHS building stocks include operational challenges in a live environment, existing aging infrastructure, varied building typology, and regulatory obstacles. With this, energy use must not increase because of refurbishment activities (Lomas and Giridharan, 2012). A further challenge is decarbonising heat; however, multiple NHS trusts have made positive changes. NHS organisations have accessed funding for heat pump upgrades via the £635 million Public Sector Decarbonisation Scheme initiated in October 2022 (Makosinski, 2023).

To support with carbon emissions, hospitals have focused on heat generation as a platform. In Wales, a £325,000 project was financed by Welsh Government following recommendations from its energy service's feasibility study, which explored low-carbon heating solutions and their integration into plant rooms to support lower temperature demands. Installing the heat pump will cut the building's carbon emissions by 30%, replacing the need for natural gas boilers in meeting heating demand (Hywel Dda University Health Board, 2022). A Ground Source Heat Pump (GSHP) that was installed at the critical care unit of St Mary's Hospital in London has cut carbon emissions by 40%, with anticipated yearly energy savings nearing £1 million for the hospital. The University Hospital of South Manchester has equipped its new outpatient centre with air source heat pumps, leading to a carbon emissions reduction exceeding 30% (Makosinski, 2023). London Northwest University Healthcare NHS Trust transitioned from steam to a low temperature hot water system, underpinned by an innovative mix of Water Source Heat Pumps (WSHPs) and ASHPs. This initiative will reduce carbon emissions by more than 2,500 tonnes annually and secure £19 million in yearly energy savings (Vital Energi, 2021). In addition to the changes made, £49.3m from the NHS Energy Efficient Fund (EEF) funded 117 projects across 48 NHS organisations in England in 2013/14 (Short *et al.*, 2015). With this, Table 1 expands on what changes hospitals around the UK have made towards climate change, and what propositions have been made for the future to achieve.

Table 1 - NHS Trusts Decarbonisation Actions and Proposals

NHS Trusts Decarbonisation Plans and Strategies		
Trust / Health Board	Changes Made	Proposed Changes
Cardiff and Vale University Health Board [CVUHB] (2023)	Decommissioning nitrous oxide manifolds which resulted in a reduction of 500 tonnes of carbon dioxide equivalent (CO₂) emissions. An annual capital allocation of £100,000 has been designated to support the continuation of the programme on a recurring basis.	Cardiff and Vale anticipate that reaching the 16% savings target by 2025 may be unlikely and are instead prioritising the promotion of positive behavioural change. Initiate a series of studies aimed at exploring long-term opportunities for energy savings and efficient renewable solutions. Track and assess electricity consumption patterns. Around 300,000kWh of renewable energy capacity are expected to be accessible. A total of 7,000 lighting units have been upgraded to Light Emitting-Diode (LED) technology, encompassing emergency fixtures and integrated smart control systems. A total of 100 fans have been replaced within the Air Handling Units (AHUs). The projected yearly reduction in carbon emissions is approximately 700 tonnes, accompanied by energy cost savings ranging between £300,000 and £350,000. Measure and observe electrical usage patterns.
Leeds Teaching Hospital NHS Trust [LTHT NHST] (2021)		Achieve carbon neutrality by the year 2040 and achieve an 80% reduction within the 2028 to 2032 timeframe or Achieve carbon neutrality by the year 2045 and achieve an 80% reduction within the 2036 to 2039 timeframe. Allocate investment to cut critical maintenance backlog by half over the next 15 years. Upgrade the building envelope and replace outdated service systems and infrastructure. Downsize the total estate footprint by the year 2035. Employ a data-informed modelling approach to evaluate projected energy usage. Enhance roofing and glazing systems while replacing existing lighting with energy-efficient LED fixtures.

		Install a heat pump system integrated with Combined Heat and Power (CHP) operations to supply space heating and domestic hot water, thereby lowering reliance on fossil fuels. Conduct a review of Building Management System (BMS) controls to enhance operational efficiency and lower energy usage. Implement enhancements to the building fabric to lower overall energy requirements. Discontinue the use of steam systems across the site.
James Paget University Hospital (2021)	Prioritise high-impact areas to drive reductions in emissions across building energy use, water consumption, waste output, and the estates facilities fleet.	Cut yearly energy expenditure by an estimated 72% to 83%. Lower GHG emissions by curbing heat loss through building structures. Adapt building infrastructure to accommodate low-carbon heating technologies. Enhance building thermal efficiency to lower energy consumption requirements.
Sherwood Forest Hospitals NHS Foundation Trust (2021)	Having eliminated landfill disposal, the trust aimed to cut overall waste tonnage by 7% annually until 2025. Cut direct emissions by 46% compared to our 2013/14 baseline, with just over 13,000 tonnes remaining to eliminate or offset.	Procure renewable energy and evaluate its carbon impact. Sustain the downward trend in electricity consumption. Team up with staff and estates to run buildings safely and efficiently, saving money and protecting the environment. Improve boiler efficiency to support a yearly 7% decrease in gas demand. Cut oil reliance by 4% annually to support environmental goals. While the trust doesn't currently use CHP systems to produce electricity on-site, it aims to install a low-carbon version—like biomass or bio-gas CHP—at King Mill's in the future.
Norfolk and Norwich University Hospitals Trust (2021)	A heat decarbonisation strategy commissioned in 2021 provides a framework for transitioning the estate away from gas-based heating and hot water systems. Transformer enhancements are being implemented to boost energy capacity and resilience.	Transitioning the estate away from fossil fuel-based energy sources. Prioritising investments in innovations that drive our shift to carbon-neutral operations, including renewables. Capitalising on asset renewal cycles to introduce higher-performing alternatives, prioritising

	A three-year rollout of BMS upgrades is underway, with initial installations completed in year one. As of mid-June 2021, most theatres have discontinued the use of volatile anaesthetic agents, notably desflurane, as part of their environmental strategy. Implementing energy-efficient upgrades to air cooling and chiller systems as part of broader plant improvements.	upgrades over direct replacements to unlock benefits like energy savings. Upgrading critical plant items, including energy generation and distribution equipment, to future-proof infrastructure. Reducing reliance on nitrous oxide, the primary driver of anaesthetic gas emissions, responsible for three-quarters of their carbon footprint. Energy consumption can be reduced through improved management, targeted upgrades to efficiency systems, operational adjustments to CHP units due to observed faults, and optimisation of the hot water distribution network.
Isle of Wight NHS Trust (Ritcher, 2021)	Maximising energy efficiency through strategic, low-risk investments. Getting buildings ready for electric heating by improving insulation and structure and investing in new energy ideas to heat buildings without fossil fuels. The main heating infrastructure has been upgraded, replacing oil-based steam with a decentralised gas-fired system.	Minimise emissions across all contributing sectors. Reaching net-zero necessitates the adoption of heat pump systems, such as air or ground source units. Refurbishment of AHU heat recovery systems and expansion of CHP infrastructure is scheduled.
Manchester University NHS Trust [MU NHST] (2021)	Implemented measures include local energy system improvements, efficiency programmes like fabric retrofits and LED deployment, underpinned by a cleaner electricity grid. Replacing fossil fuel heating with more sustainable options. Boosting the contribution of locally sourced renewables.	£18 million has been allocated for decarbonising hospital buildings through targeted upgrades.
York and Scarborough Teaching Hospitals NHS Foundation Trust [YSTH NHSFT] (IHEEM, 2023)	200kW ASHPs installed at York Hospital. Vital Energi retrofitted York Hospital's energy centre in 2016, implementing conservation technologies that guaranteed the trust over £12 million in energy savings and a reduction of 45,000 tonnes of carbon emissions across a 15-year agreement.	Vital Energi will refurbish the structural fabric of the three-level ward block to improve performance. Dating back to the 1970s, the building exhibits poor insulation and considerable thermal losses via its envelope and glazing, contributing to increased energy consumption.
University Hospitals Bristol and Weston NHS Foundation Trust [UHBW NHSFT]	The trust began phase one of its Bristol estate de-steaming strategy in 2020, implementing a heat network across four hospital sites and deploying a CHP engine to support project funding.	Residual steam boilers are to be replaced by dual-fuel gas units configured for LTHW distribution.

(Energy Managers Association, 2023).	A 5.86MW boiler replaced a steam unit and can switch to Low Temperature Hot Water (LTHW) in phase two.	
Bolton NHS Foundation Trust (2022)	Developing a CHP plant for onsite energy production, enabling the phase-out of coal usage. Using a bore well to cut mains water usage. LED lighting installation programme. Enhancements to structural and thermal components of the facility.	A Computer Aided Facilities Management (CAFM) platform is being introduced to streamline asset information management and enable structured preventative maintenance planning. Define sustainable design criteria to guide all future new builds and renovation works.
University Hospitals Coventry and Warwickshire NHS Trusts [UHCW NHST] (2022)	Measures undertaken involve LED lighting replacement, BMS enhancements, and grant applications to support the integration of solar photovoltaic panels and air source heat pump technology. University Hospital now operates a combined heat and power system that generates half of its on-site electricity demand.	

As mentioned, heat generation has been a focus for many hospitals. The withdrawal of fossil fuels can be seen as a goal for all NHS trusts, with many opting for heat pumps as a replacement.

2.3 Heat Pumps

2.3.1 Operational Principles

A strategy that has been explored and has been found to be used out in the field, for reducing carbon emissions is heat pumps. Usually used for space or hot water heating, a heat pump is a device that transfers heat energy from a heat source, such as ground, air or water, to a higher-temperature heat sink using a refrigeration cycle (Department for Energy Security & Net Zero, 2023). Based on a refrigeration process dating back to the 1800s, this technology was first adapted for heating buildings in the early 1900s (Burns and Strachan, 2021). A heat pump includes a compressor that circulates refrigerant through a refrigeration loop, along with a heat exchanger that draws thermal energy from the source. This heat is then transferred to a heat sink via a second heat exchanger (Acke et al., 2022). Figures 3 & 4 show the components of an ASHP.

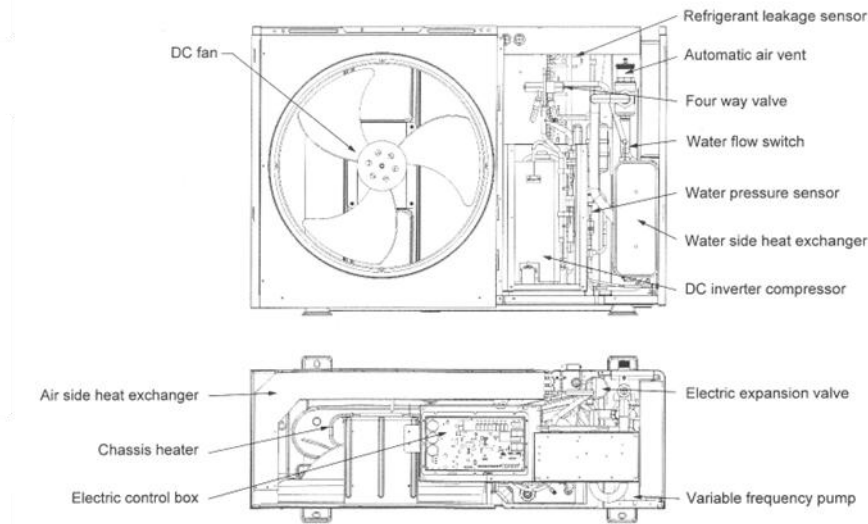


Figure 3 - ASHP Diagram (Grant Engineering UK, 2024)

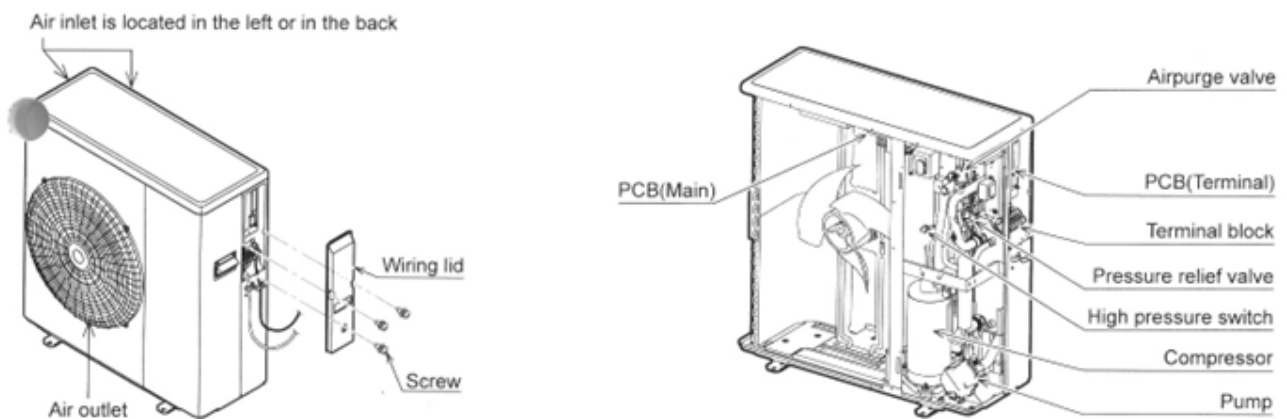


Figure 4 - ASHP Diagram (Grant Engineering UK, 2024)

A principle initially demonstrated by Scottish physician William Cullen in 1755 (Olson, 2020), delivery of thermal comfort across various built environments, including residential, healthcare, commercial, and office facilities is the focus today (Nikitin *et al.*, 2021). Heat pumps transfer heat by exploiting the principles of compression and phase change in refrigerants. The system draws heat from the outside air, which acts as the heat source. Figure 5 demonstrates the stages of the ASHP cycle, with Figure 6 showing how the heat transfers to a property.

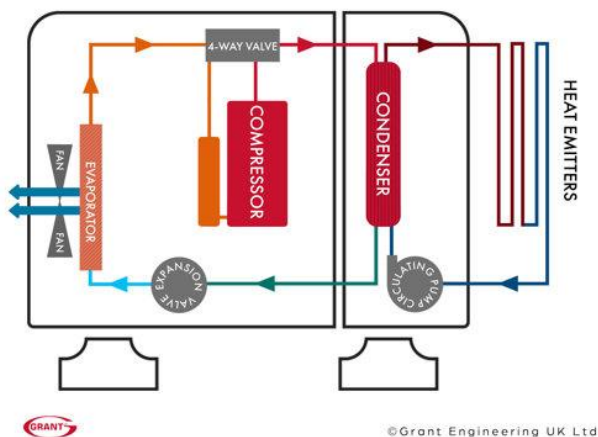


Figure 5 - ASHP Internal Workings Diagram (Grant Engineering UK, 2020)

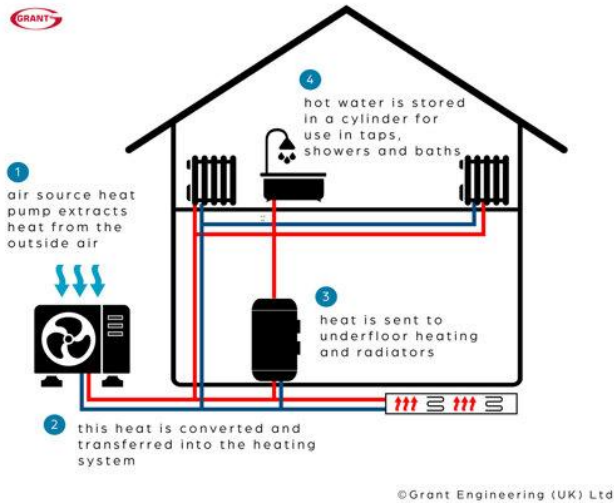


Figure 6 - ASHP Domestic Distribution Diagram (Grant Engineering UK, 2020)

The refrigerant, a substance that alternates between liquid and gas, absorbs and releases heat as it changes state. Key components include outdoor and indoor coils, a compressor, and an expansion valve. In heating mode, the outdoor coil functions as an evaporator, where the refrigerant absorbs heat from the air and vaporizes. The resulting hot gas flows through the indoor coil, where a fan distributes the heat into the room air (Gerring, 2024). Heat pumps utilise the reversed Carnot cycle, a thermodynamic process that enables efficient heat transfer, as seen below in Figure 7 (Danza *et al.*, 2016).

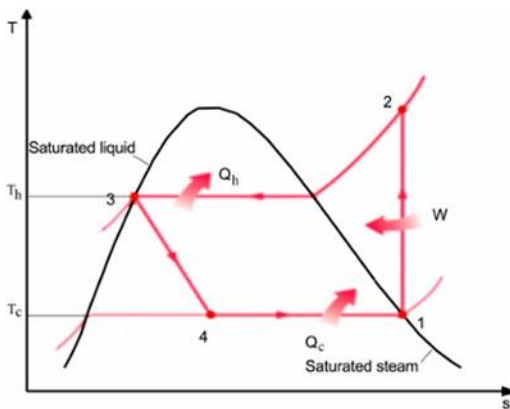


Figure 7 - Refrigeration Cycle represented on the entropy-temperature plan (Danza *et al.*, 2016)

Verifying the estimated Seasonal Coefficient of Performance (SCOP) under actual operating conditions is essential. The metric used to assess the real-world seasonal performance of a heat pump in heating mode is known as the Seasonal Performance Factor (SPF) (Pater & Ciesielczyk, 2017). The SPF is a metric that assesses the efficiency of heat pumps by comparing the total annual heat delivered to a building with the electrical energy consumed to operate the system. This includes the compressor as well as auxiliary components like circulation pumps and control valves. An SPF of 2.5 indicates that, over the course of a year, the heat pump supplies 2.5 times more thermal energy than the electrical energy it uses. A higher SPF indicates that the system is converting electricity into heat more effectively (Lee, 2023).

2.3.2 Strategic Value

2.3.2.1 Sustainability

In addition to being cost-effective, using a heat pump system for heating is essential for preserving the environment and natural resources (Kul and Uğural, 2022). Looking at a decarbonised future, Koroli and Ishnazarov (2020) believe that heat pump technology stands out as a leading solution in energy efficiency and environmentally sustainable systems. The Department for Business, Energy & Industrial Strategy (2021) have praised the superior efficiency of heat pumps and have stated that they are a top choice in today's market. With this, Taylor *et al.* (2023) view heat pumps as safe and dependable systems that operate quietly

and perform well for both space heating and hot water needs. Sun *et al.* (2022) have discussed that the main advantages of ASHPs include minimal environmental impact, high performance, and a clean energy profile. In addition, a narrower temperature differential between source and emitter enhances overall performance, which supports heat pumps to move energy, with higher gradients accelerating the process (Harris and Walker, 2023, Perko *et al.*, 2011). Today's large heat pumps can reach temperatures of 140–160°C, with further increases achievable through design enhancements and innovation (Acke *et al.*, 2022). Furthermore, Condego *et al.* (2022) discuss the ease of install at economical prices, heat pumps also emerge as a promising solution in district heating and cooling infrastructures, with Kul and Uğural (2020) arguing that switching to a heat pump system for heating not only reduces costs but also plays a vital role in conserving natural resources and safeguarding the environment. Evidence points to significantly lower installation costs and disruption for heat pumps than previously anticipated (Dwyer, 2025). Following this, heat pumps deliver the greatest cost savings of renewable heat sources, estimated at 22.47% (Sandoval *et al.*, 2023). User satisfaction was greater among heat pump owners (67%) compared to those with gas boilers (59%) (Taylor *et al.*, 2023). To further encourage installation of heat pumps, between 2023 and 2025, the Heat Network Efficiency Scheme (HNES) allocated £32 million to support upgrades to existing district and communal heating systems in England and Wales, open to public, private, and third sector applicants (Lee, 2023).

2.3.2.2 Marketability

Heat pumps deliver three to four times the efficiency of traditional fossil fuel systems, significantly boosting heating performance and switching from natural gas, oil, and solid fuel boilers to heat pumps will yield substantial environmental and energy benefits (Congedo *et al.*, 2022, pp. 3). With this, due in large part to the robust governmental support in the top markets, such as France, Italy, and Poland, heat pump sales are already increasing quickly, rising by 35% to approximately 2 million in 2021 (Acke *et al.*, 2022). Following the European Union's lead, by 2028, the UK government hopes to have 600,000 heat pump installations annually (Taylor *et al.*, 2023), with adherence to the Ten Point Plan that was unveiled in 2020 (Ehsan and Preece, 2022). Before the government set out these figures, up until November 2020, more than 2,305 heat pumps (including ground, water, and air source systems) had been certified under the NDRHI, contributing an estimated 265.4MW of total installed capacity (Department for Business, Energy & Industrial Strategy, 2021).

2.3.2.3 Efficiency

Electrically powered heat pumps with minimal emissions play a pivotal role in advancing secure and environmentally responsible heating systems according to Acke *et al.* (2022). By relying on heat transfer rather than generation, heat pumps deliver multiple units of heat for each unit of electricity used, outperforming boilers and electric heaters in both efficiency and operating cost. Additionally, despite operating on emission-heavy electricity, today's refrigerant-based heat pumps outperform gas boilers by reducing emissions by no less than 20%. Compared to gas boilers, the system demonstrates substantially reduced energy demand during the winter months of November through January (Manners, Yang and White, 2022). To support this, the City of Westminster (2023) have found that standard domestic gas boilers operate at roughly 93% efficiency, meaning 7% of the energy is lost via the flue. In contrast, heat pumps can achieve around 400% efficiency, delivering four units of heat for every unit of electricity consumed. Vishnubhotla *et al.* (2025) established that ASHPs offer a significant environmental benefit, with the capacity to reduce carbon emissions by up to 1,900 kg per year. Additionally, when designed and operated correctly, a heat pump system can meet user expectations by ensuring comfort, reliability, safety, and ease of use—while also offering low energy consumption, future resilience, and cost-effectiveness over its lifespan (Bird *et al.*, 2022). According to Manners, Yang and White (2022), buildings with sufficient insulation and ASHP systems recorded the lowest carbon emissions during winter. With this, although in 2008 they cost 10% more, ASHPs retrofitted in Scotland produced 12% less carbon than conventional gas boiler (Caroll, Chessser and Lyons, 2020). Among all building types, hospitals and both primary and secondary schools achieve the highest reductions in site energy use following installation of heat pumps (Woldekidan, 2024). However, despite being prominently featured in energy models, heat pumps contributed only modestly by 2014, representing 4% of renewable heat and less than 0.2% of overall heat generation (MacLean *et al.*, 2016).

2.3.3 Implementation Challenges

2.3.3.1 Building Fabric

Heat pumps operate most efficiently in buildings that are well insulated, where effective insulation helps reduce the energy required to keep a building warm, which adds further cost on older, inefficient buildings. Whereas well-insulated buildings require less heat, allowing low-temperature heat pumps to operate more efficiently and effectively (Carroll, Chesser and Lyons, 2020, Harris and Walker, 2023, Building Research Establishment, 2022, Vishnubhotla *et al.*, 2024). With this, upfront costs, the inefficiency of existing structures, a lack of equipment space, and the noise levels of air source heat pumps are the primary obstacles to installation (Rivers, 2020, Duindam, 2022, Orton, 2023). Additionally, radiator improvements are a common part of UK heat pump retrofits following boiler replacement (Dwyer, 2025), whereas the capacity of pipework must be sufficient to maintain low-temperature heat flow to the heating emitters incurring potential further costs (Dwyer, 2025, Harris and Walker, 2023). Also, whilst retrofitting, default air change rates should not be used, as they are often excessively high, as seen in Figure 8 for a healthcare facility. An air test is recommended to determine and apply the building's actual ventilation rate (Department of Health, 2021, Clarke, Still and Godber, 2024).

Application	Ventilation	Air-change rate (ac/h)	Pressure (Pascal – Pa)	Supply filter grade (BS EN 16798)	Noise (dB(A))	Temp (°C)	Comments (for further information see Chapter 8)
General ward (level 0 and 1 care)	S/N	6	–	SUP2	35	18–28	
Communal ward toilet	E	6	–ve	–	45	–	
Single room	S/E/N	6	0 or –ve	SUP2	35	18–28	
Single room WC	E	3	–ve	–	45	–	
Clean utility	S	6	+ve	SUP3	45	18–22	
Dirty utility (ward)	E	6	–ve	–	45	–	Refer to appendix 7 for operating theatre dirty utility
Ward isolation room (PPV/L)	S	10	Lobby + 10 Room 0	SUP2	35	–	See Welsh Health Building Note 04-01 (Supplement 1) also table 4
Ward isolation room (Negative Pressure)	S & E	10	-5 to -10	SUP2	35	18–22	See WHBN 04-01 supplement 2
Infectious diseases isolation room	E	10	–5	SUP2	35	–	See Table 4
Neutropaenic patient ward	S	10	+15	H12	35	–	See Table 3
Critical care areas (level 2 and 3 care)	S	10	+10	SUP1	35	–	Isolation room may be –ve pressure or PPV. See Table 3
Birth room	S & E	10	0	SUP2	35	20–25	See Table 5
NICU/SCBU	S & E	10	+5	SUP1	45	20–28	Isolation room may be –ve pressure
For general and UCV operating suites and associated rooms, see specific guidance in Chapter 8 and typical design solutions in Appendix 7							
Operating department recovery room	S & E	15	0	SUP2	45	18–25	Provide clean airflow path
Catheterisation room	S & E	10	+ve	SUP2	45	18–22	

Application	Ventilation	Air-change rate (ac/h)	Pressure (Pascal – Pa)	Supply filter grade (BS EN 16798)	Noise (dB(A))	Temp (°C)	Comments (for further information see Chapter 8)
Interventional or noninterventional Imaging room of any type	S & E	10	+ve	SUP2	48	–	Stable conditions as specified for the imaging equipment
Sedation recovery room as in paragraph 8.16	S & E	10	Neutral	SUP2	45	18–28	
Endoscopic procedure room	S & E	10	-5	SUP2	40	20–25	See Table 2
Endoscope reprocessing wash room	E	10	–ve	–	45	–	
General treatment room	S & E	10	Neutral	SUP2	45	20–25	See Table 2
Emergency department waiting area	S & E	6	–	SUP2	–	18–25	See Table 2
Containment level 3 laboratory	#	>20	#	H14*	–	18–22	# See ACDP guide; *Filter in extract See Table 4
Post-mortem room	S & E	S = 10 E = 12	–ve	SUP2	45	18–22	Provide clean airflow path
Specimen store	E	–	–ve	–	–	–	Fan accessible from outside of store

Notes:

Waiting and circulation areas should be directly or indirectly ventilated to provide a comfortable environment and control airborne contamination and odours.

18–22°C indicates the range over which the temperature may float.

18–22°C indicates the range over which the temperature should be capable of being controlled.

S = Supply
E = Extract
N = Natural ventilation where possible

Figure 8 - Ventilation requirements for healthcare facilities in Wales (Department of Health, 2021)

2.3.3.2 Grid Demand

It has been highlighted that one of the biggest challenges of installing and operating heat pumps is the grid demand. Deploying heat pumps will increase electricity demand, driven by the substantial expansion of heat electrification - necessitating additional power generation and grid reinforcement (Department for Business, Energy & Industrial Strategy, 2021), and it is believed that the primary expense associated with operating heat pump systems is the cost of the electricity they consume (Kul and Uğural, 2022). In addition, installing a heat pump might necessitate upgrades or modifications to the building's current electrical system (Gerring, 2024), however, with the deployment of renewable electricity, rapidly increasing heat pump installations becomes a powerful strategy to curb fossil gas use (Pietro *et al.*, 2023). With this, as grid power is becoming less carbon-intensive, installing a heat pump can reduce carbon dioxide emissions by 55-65% compared to a modern gas boiler (Rivers, 2020). However, heat pumps typically operate at lower output temperatures (~35°C-50°C) compared to traditional boilers (~70°C), which means they often need larger radiators to deliver adequate heating, and reinforced with hot water cylinders (Ehsan and Preece, 2022). Further to this, to meet heating requirements in larger facilities, multiple external units may be necessary. These units require unobstructed space of 30 to 91 cm around them and must be safeguarded against environmental hazards like snow, ice, and floodwater (Gerring, 2024).

2.3.3.3 Seasonal Performance

In addition, the efficiency of heat pumps is influenced by seasonal changes and the specific conditions of each building (Burns and Strachan, 2021). In colder, wetter climates, such as the UK during the Autumn and Winter months, their efficiency drops, posing challenges during periods of peak heating need, where the accumulation of ice during colder months impedes airflow, resulting in a progressive decline in airflow rate (Ding *et al.*, 2021, Sezen, 2023, Manners, Yang and White, 2022). Electrification is a decarbonisation strategy that is being looked at, where there are concerns with where the electricity is generated from. However, replacing fossil fuel boilers with heat pumps presents the greatest potential for electrification (Sandoval *et al.*, 2023), where heat pumps powered by renewable energy are emerging as a cornerstone of future energy systems (Naumann, Schropp and Gadarer, 2022). Substantial electrical input is consequently necessary to support system operation (Tao, Zheng & Wu, 2021), however, given the carbon-heavy nature of electricity generation, heat pumps do not consistently deliver better environmental performance than condensing gas boilers (Norouzi *et al.*, 2023). Evidence also suggests that heat pumps can underperform, and place increased mechanical load on the compressor, where suboptimal performance is often linked to deficiencies in design, installation or system operation (Kim *et al.*, 2024, Sezen, 2023). With this, under Approved Document Part L4 of the Building Regulations in England and Wales, ASHPs are deemed acceptable for space heating applications only when their Coefficient of Performance (COP) is no less than 2.2 (Dwyer, 2012).

2.3.3.4 Efficiency

Cattini-Dow *et al.* (2022) report that most heat pumps operate more efficiently when the temperature of the water they supply is lower. As a result, heating systems are typically designed to run at reduced flow temperatures to enhance efficiency, lower energy costs, and minimise carbon emissions. In contrast to conventional gas boilers with flow rates of 55–70°C, heat pumps often achieve optimal efficiency at 35–55°C. This discrepancy may hinder retrofit applications in buildings with poor thermal performance and legacy heat emitters designed for higher operating temperatures (Rivers, 2020).

2.3.4 Environmental Impacts

Considering the multiple environmental benefits, there are also discharges from ASHP's that effect the environment. The expanded use of heat pumps presents a potential risk of fluorinated gas emissions, where an estimated 2.4% of total GHG emissions globally are directly from f-gases, with an annual refrigerant leakage rate of approximately 3.5% is commonly observed (Acke *et al.*, 2022, Storch and Stamford, 2021). Hydrofluorocarbons (HFCs) represent the dominant class of f-gases currently used in heat pumps and refrigeration equipment, accounting for more than 85% of global production (Acke *et al.*, 2022). Although HFC refrigerants such as R134a and R410a are widely used in heat pumps, refrigeration, and air conditioning, the Kigali Amendment mandates an 85% reduction in their use by 2036 owing to their significant global warming potential (Bird *et al.*, 2022).

Despite full refrigerant leakage and reliance on emissions-heavy electricity, modern heat pumps outperform high-efficiency gas boilers by reducing GHG emissions by no less than 20% (Acke *et al.*, 2022). There are promising options for refrigerants are those that eliminate ozone depletion risk and maintain a low climate impact, with Global Warming Potential (GWP) values ideally under 150, where also switching to low-GWP fluid combinations like R1234ze(E)/HP-1 yields a modest performance gain, about 3.05%, relative to conventional refrigerants (Dong, Yan and Wang, 2024).

2.3.5 Systems

A heat pump's technology is like that of refrigerators and air conditioners. It takes heat from a number of sources, such as the surrounding air, geothermal energy stored in the earth, nearby water sources, or waste heat from industrial. After that, it distributes the heat where it is required, however in this instance, energy from the air is used to heat up water for space heating and hot water (Acke *et al.*, 2022, Carroll, Chesser and Lyons, 2020).

ASHPs are classified into monobloc and direct expansion systems, depending on where the condenser is located. Monobloc (air-to-water) units contain the condenser within the outdoor assembly and can connect directly to wet heating systems like radiators or underfloor heating, using water-filled pipework between the

external unit and the building. In contrast, direct expansion (air-to-air) systems feature a remotely located condenser. Additionally, a monovalent system uses a heat pump sized to handle the building's entire peak heating demand without relying on additional heating technologies (Cattini-Dow *et al.*, 2022).

In conjunction with the system type, accurate sizing of heat pumps is crucial to match heating demand. This involves calculating the building's peak load and heat loss to ensure sufficient heat output for comfortable indoor conditions. To maximise efficiency, heat pump systems require a detailed breakdown of heat loss by building element. Quantifying losses through walls, floors, roofs, and glazing helps designers evaluate the impact of proposed improvements to the building envelope (Cattini-Dow *et al.*, 2022). A further method is a Building Energy Modelling (BEM), which is a simulation method used to estimate a building's energy consumption. It provides detailed insights for individual zones as well as the entire building, including calculations of heat gains and losses, internal temperature regulation, sources of thermal inefficiency, and the energy costs associated with maintaining occupant comfort (Odineca *et al.*, 2019).

A supplementary consideration is that radiators originally sized for boiler systems may be less effective when paired with ASHPs, which operate at lower water temperatures and can limit heat transfer into the space, therefore, upsizing of radiators are required to match the space heating performance of a conventional gas system (City of Westminster, 2023, Vishnubhotla *et al.*, 2024).

2.4 Summary

With the above findings, it is clear to see that the health sector is an area with many gaps in research when it comes to decarbonising. The hard work that has been carried out across the NHS to reduce carbon emissions has been noted, however with cost and resource being a major issue, the NHS is a way off reaching targets set for GHG reduction. As found, the building stock of the NHS is varied, from 40+ year old buildings, modular and temporary buildings, to brand new facilities. There is a clear gap in research when it comes to the impact of different types of buildings on decarbonisation, with uncertainty on how well decarbonising methods will work depending on fabric, air permeability, and usage of the building. Following this, to assist the NHS with decarbonising, this project will focus on a particularly challenging building that is often found within the NHS building stock, with poor building fabric, and a temporary-permanent approach when placed on an NHS site, and whether the conventional Low Pressure Hot Water (LPHW) set up can be improved with a focus on reducing carbon emissions.

3.0 Methodology

To achieve the aim and objectives set, and for comparison, there will be a focus on two methods to assist: a room-by-room heat loss calculation, and Passive House Planning Package (PHPP) model. These quantitative methods will allow clear guidance on the size of ASHP required for the chosen building, along with emitter sizes, pipe sizes, heat losses and gains.

3.1 Building

The chosen building (Building J) can be seen in Figures 9 & 10. Building J is located on the site of a large hospital in South Wales, as seen in Figure 11. Since being built in 2005, the purpose of Building J has changed from providing Renal Dialysis, to now accommodating outpatients who receive diagnosis and treatment for neurological disorders.

The building's outer walls are constructed of a stone finish with duplex plasterboard, and solid sheet insulation adjoined into a timber frame, with internal walls made up of plasterboard. The roof is supported by a galvanised steel beam and purlins, with a 5-degree slope, with steel composite insulated sheeting and plastic-coated steel as the warm deck construction. The floor frame is galvanised steel beams and cross joints, with exterior grade plywood and rigid sheet foam to finish.

Heating is generated from two gas boilers located in the rear plant room, that feeds radiators within the building, followed by a gas fired cylinder generating hot water, that distributes to outlets. The building is required to be heated during the late autumn, winter, and early spring periods. Following this, hot water is required throughout the year, for hand-washing and disinfecting any equipment. Mechanical ventilation is

installed within the building, however, is not operational, therefore only natural ventilation is available. There is a medical vacuum plant installed in the rear plan room, that is used to remove fluids, other gases and debris during procedures. In the event of a power failure, a generator on the hospital site will provide back-up power to Building J to ensure no disruption to service. Further information on Building J can be found in Appendix A. With the services listed, there will be a focus on improving the heating system within Building J, given the challenges with achieving the required temperatures for hot water within a hospital setting, with storage being over 60°C and distribution of 55°C (Department of Health, 2016), and clear limitations with ASHPs unable to achieve high temperatures.

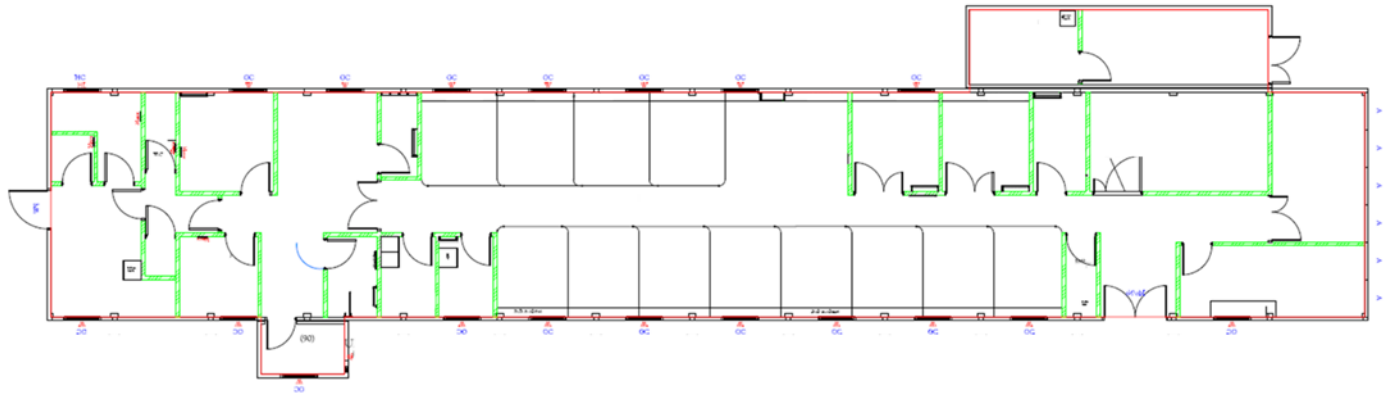


Figure 9 - Floor Plan of Building J



Figure 10 - Building J Exterior a. North-West Side b. North-East Side



Figure 11 -Building J Location on Large Hospital Site in South Wales (Google, 2026b)

3.2 Method 1 – Room-by-Room Heat Loss Calculation

In line with CIBSE (2021) guidance, Building Regulations Part L, and manufacturers guidance from Grant Engineering (2016, 2019, 2020, 2023, 2024), a room-by-room calculation is required in Wales to determine the heat losses of a building. This is to mitigate oversizing systems to improve efficiency and reduce running costs, by ensuring the correct emitter sizes are calculated. This guidance is aimed at domestic buildings; however, Building J is similar in size. With this, the worksheet seen in Appendix B.1 and supporting document in Appendix B.2 will be followed to determine the heat loss of each room in Building J. Following this, the heat losses will be combined to determine the size of ASHP required to heat the building. From information in Appendix A, it is expected that there will be significant losses through the ventilation, with suspected poor airtightness. In addition, the fabric of the building is not considered efficient, which could have an impact on losing heat.

3.3 Method 2 – PHPP Modelling

The second method to be used to determine the size of ASHP required for Building J is to model the building using PHPP. Through following guidance by Feist *et al.* (2022), relevant information around Building J will be inputted into the PHPP software, to model its efficiency, determining the heat losses and gains, where once again the size of ASHP can be determined. This method differs to the first as it considers a whole building energy-balance rather than individual rooms. With this, the internal gains are assumed as more realistic values, and total annual energy demand for heating is required for sizing emitters, which PHPP calculates. Accurate and up-to-date climate data is used, with solar radiation, temperatures and shading all considered, which all have impacts on the final energy-balance calculation.

3.4 Gas & Electricity Consumption

Subsequently to acquiring the size of ASHP required from both methods above, the gas and electricity consumption of the building can then be evaluated. Actual gas and electricity data for Building J will be collected, where consumptions will be reviewed per month of collection, recognising patterns or discrepancies, with the view to improving the usage of the building following a theoretical introduction of an ASHP, with theoretical data compiled to estimate potential savings for the health board.

4.0 Results and Discussion

4.1 Method 1 – Room-by-Room Heat Loss Calculation

Figure 12 was used to determine the heat losses of each individual room within Building J. The rooms have been labelled from 'a)' to 't)'. The rear Plant Room has not been considered as part of the calculation. All calculations and results can be seen in Appendix B.

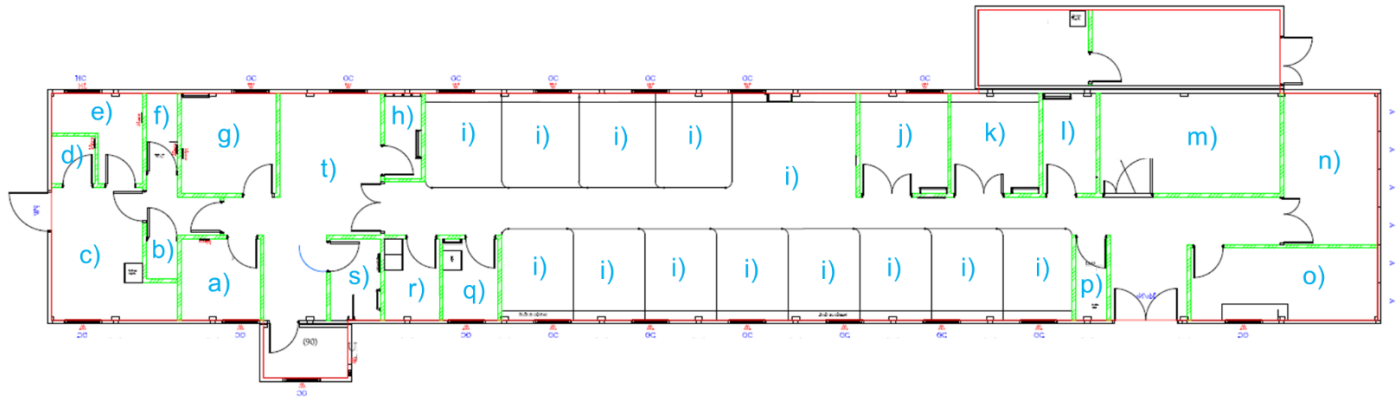


Figure 12 - Building J Room Labelling for Heat Loss Calculation

For each room, dimensions were taken (Height, Width and Length) along with details of building fabric (U-values) to determine the current heat loss. It was predicted that due to the fabric of the building, as seen in Appendix A.16, that the building would not be efficient, in the context of high-performing insulation and airtightness, given that the modular building was designed for the purpose of being temporary, therefore focus on efficiency was not a priority from the constructor. Additionally, in 2005, there was less knowledge surrounding efficient buildings, and the impact on inefficiency on wasted energy and the average energy bill.

Table 2 - Total Heat Losses of Building J per Room (kWh)

Total Heat Loss – Building J						
Room Reference	Room Name	ACH	Ventilation Heat Loss (kWh)	Fabric Heat Loss (kWh)	Oversize Factor	Total Heat Loss (kWh)
a)	Nursing Office	6	0.72	0.23	1.2	1.15
b)	Data Cupboard	1	0.03	0.02	1.2	0.06
c)	Staff Room	6	1.50	0.71	1.2	2.65
d)	Male Changing Room	6	0.25	0.08	1.2	0.40
e)	Female Changing Room	6	0.68	0.21	1.2	1.07
f)	WC	6	0.32	0.07	1.2	0.47
g)	Consulting	6	0.97	0.27	1.2	1.49
h)	WC	6	0.35	0.08	1.2	0.51
i)	Treatment Area	6	15.66	4.32	1.2	23.97
j)	Isolation Room	10	1.66	0.27	1.2	2.32
k)	Line Insertion Room	6	1.00	0.27	1.2	1.53
l)	Dirty Utility	6	0.61	0.08	1.2	0.82
m)	Water Treatment	4	1.36	0.28	1.2	1.97
n)	Store	6	1.60	0.64	1.2	2.69
o)	Workshop	6	1.52	0.75	1.2	2.72
p)	Cleaners Store	6	0.50	0.09	1.2	0.71
q)	Clean Utility	6	0.51	0.17	1.2	0.82
r)	Kitchen	6	0.51	0.12	1.2	0.75
s)	Disabled WC	6	0.46	0.08	1.2	0.66
t)	Waiting Area	6	1.96	0.44	1.2	2.88
u)	Corridor	6	0.43	0.06	1.2	0.58
			32.58	9.26		50.21

Whilst carrying out the heat loss calculation for the building, it was made apparent that the theoretical ventilation rate for the building that was required to be achieved was having an impact on the results. It can be seen in Table 2 that the higher heat losses are through ventilation. There can be seen a total ventilation heat loss of around 32kWh, whereas only around 9kWh through the fabric. The requirements for healthcare building ventilation can be seen in Figure 7, where an average Air Changes per Hour (ACH) of 6 is required per room, which is the measurement of the number of times the total air volume of a room or building is replaced with outside air in one hour. The room usage and occupancy will determine the ACH required for the room, with odours activity also having an impact. With this, a large volume of indoor air is replaced with outdoor air in Building J, where in winter is colder, requiring the heating system to work harder to maintain human comfort, contributing to major inefficiencies in energy use.

To further add to this, with the building in use from 07.00am to 20.00pm, Monday to Friday, to increase value for money and not heating an un-occupied space, an 11-hour period of disuse was adopted to also ensure that the building was up to temperature when occupants arrive. Appendix B demonstrates that for every room, the re-heat kW's are much lower than the heat losses, in most cases around half the amount. This would subsequently not suffice an ASHP installation, due to the heat pump requiring to run continuously to maintain the temperature, even with an oversize of 20%, the maximum recommended by CIBSE (2021). The purpose of an oversize factor is to ensure that the system is reliable during colder periods.

As identified in Table 2 through a heat map method, the total heat losses for Building J, by using the room-by-room method, appear to be very high, with the re-heat values being extremely low, not being able to

compete with the heat required for the building, making the ASHP inefficient. Building J loses around 50kWh of heat. On average, a typical room within Building J loses 1.55kWh of heat through ventilation losses, and 0.44kWh of heat through the building fabric, with an overall average of 2.39kWh lost from the building through the combination of ventilation and building fabric.

As expected, the smaller rooms lose less heat, with minimal heat required for the room, such as the Data Cupboard, Male Changing Room, WCs, Dirty Utilities and Kitchen areas. With this, there are fewer paths for the heat to be lost, with fewer windows and external walls, with an average of 0.58kWh. The lowest heat loss can be seen in the data cupboard, with a low ACH requirement, and small floor area, with no external walls, at 0.05kWh with the higher end of the lower heat losses at 0.82kWh from the dirty utility.

Rooms with the bigger floor area, such as the Staff Room, Treatment Areas, Waiting Area, Offices and Stores, can be seen with the higher heat losses, contrary to the smaller rooms. An average heat loss of 4kWh has been calculated, with the lowest heat loss at 1.07kWh from the Female Changing Room, and the highest from the Treatment Room, at 23.97kWh, with this area contributing to just under half of the heat losses from the building, leaving a further 26.24kWh for the rest of the building.

The Room-by-Room heat loss calculation demonstrates that Building J is inefficient, with a high heat loss, however, no further factors are considered using this method, such as heat gains, detailed building fabric information and window glazing. Therefore, this method does not accurately reflect the efficiency of Building J and the suitability of an ASHP to replace the gas boilers.

4.2 Method 2 – PHPP Modelling

With the challenges above, the PHPP package required further detail to be included, to produce an accurate energy efficiency model for the building. Information in Appendix A was once again used, with further information also entered.

4.2.1 Verification

The project settings were inputted as a retrofit, given the existing building receiving a new heat source. Following this, the energy demand method was adopted, as the whole building required to achieve improved energy performance by staying within rigorously defined energy-demand limits. Further to this, no renewable energy sources were to be used.

4.2.2 Climate

Climate region of Severn (Zone 06), with the climate data set of Swansea (GB0023a) was chosen. Building J is also set at 96m above sea level. Figure 13 shows the radiation of each orientation in the climate area chosen, along with the horizontal radiation, dew point temperature and exterior temperature, over a period of 12-months, relating to temperature and kWh/m².

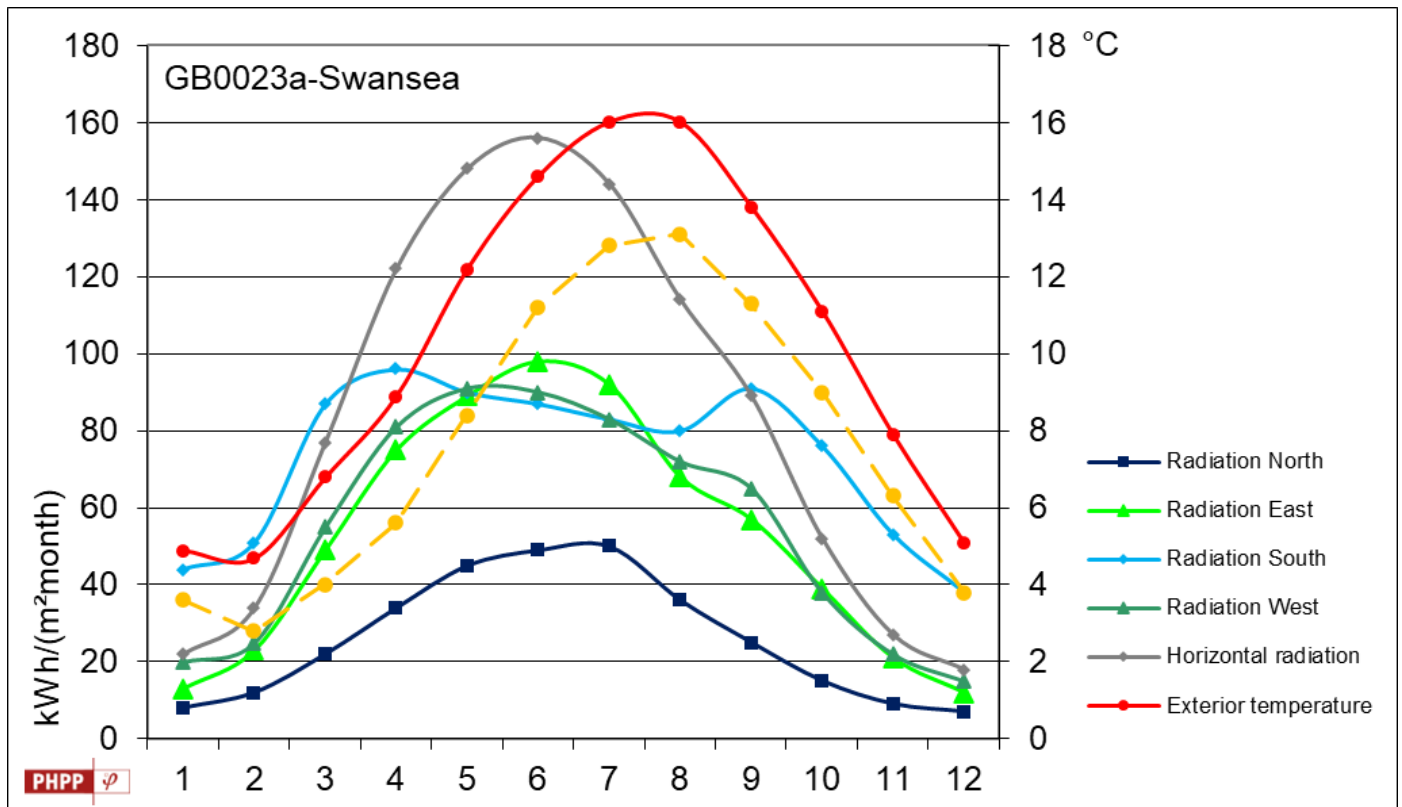


Figure 13 - Building J Radiation of Orientations from Climate Location GB0023a-Swansea

4.2.3 U-Values & Areas

The building assembly was processed with the relevant U-values from Appendix A. The roof, walls and floor were created. This allowed the areas to be accurately inputted, with further detail such as deviation from North, angle of inclination, reduction shading factor, absorptivity and emissivity, which were important for solar gain. It was calculated that Building J has a Treated Floor Area (TFA) of 295.21 m², with an overall thermal envelope of 875.74 m². All U-values can be seen in Figure 14, where an average U-value of the thermal envelope was calculated as 0.430 W/m²K, which is considered a poor U-value.

Summary				Average U-value [W/(m²K)]	Radiation gains Heating period [kWh/a]	Radiation load Cooling period [kWh/a]
Temp. zone	Thermal envelope Areas [m²]	Area group	Group no.			
	295.21	Treated floor area	1		12 months	12 months
A	12.16	North windows	2	6.270	937	1066
A	0.00	East windows	3			
A	9.59	South windows	4	6.265	2403	2563
A	0.00	West windows	5			
A	0.00	Horizontal windows	6			
A	3.07	Exterior door	7	2.300		
A	239.12	External wall - ambient	8	0.338	498	512
B	0.00	External wall ground/basement	9			
A	306.30	Roof / ceiling - ambient	10	0.250	1899	1919
B	305.51	Floor slab / basement ceiling	11	0.250		
	0.00		12			
	0.00		13			
	0.00		14			
Thermal bridges, length [m]				Ψ [W/(m²K)]		
A	0.00	Thermal bridges ambient	15			
P	0.00	Perimeter thermal bridges	16			
B	0.00	Thermal bridges FS/BC	17			
Building element towards neighbour, [m²]				[W/(m²K)]		
I	0.00	Building element towards neighbour	18			
Total thermal envelope [m²]				[W/(m²K)]		
	875.74	Average U-value of thermal envelope:		0.430		

Figure 14 - Building J Summary of Areas

4.2.5 Ground

Figure 15 shows the heat flows into the ground of Building J per month. For these to be calculated, information from the areas tab was required, which was automatically filled in, following pre-written PHPP formulas. Details on wind velocity and shield factor were required for a suspended floor above a ventilated crawl space. There are higher heat flows during the winter months with the heating demand. Natural heat is flowing through the ground during the summer months. Cooling on this occasion was discarded.

Heat flow into the ground for monthly method (all building parts)

Month	1	2	3	4	5	6	7	8	9	10	11	12	Avg. value
heat flow	591	624	629	604	556	498	445	412	407	432	480	538	518

Design ground temperature for 'Heating load' worksheet

11.8

For 'Cooling load' worksheet

19.2

Temperature reduction factor for 'Annual Heating' worksheet

0.55

Figure 15 - Building J Monthly Heat Flows into Ground

4.2.6 Components & Windows

Passive House certified components are available in the modelling software, however, were not required as the actual building assemblies from Building J were pre-populated from the U-Value tab, such as the roof, walls and floor. Window and door details, glazing and frames, were inputted from information in Appendix A, with again unused Passive House certified options. This included details of opening casements, fixed glazing, and transoms. No further components were required for the building, given the lack of mechanical ventilation installed in Building J.

All windows installed in the building were then added to the Windows tab, with 18 windows in total, and 2 with deviating dimensions to the others. This then allowed the model to pre-calculate the window area, glazing area, fraction of glazing per window, U-Value of the window, and heat gains.

Radiation values have been calculated for all orientations, along with shading and glazing factor. The South can be seen to have the highest radiation, with the East and West having the highest shading. The glazing area can also be seen as 12.94m². With this, losses in the heating period have been calculated as 11,856kWh/a, and solar gains from radiation as 3,340kWh/a, with these values descending from the North and South elevations.

Wind ow orient ation	Global radiation (main direction) Standard values → kWh/(m ² a)	Shading 0.75	Dirt 0.95	Non-perpendic ular radiation incidence 0.85	Glazing fraction 0.60	g-value 0.65	Solar irradiation reduction factor 0.31	Window area m ² 12.2	Window U _w installed W/(m ² K) 6.27	Glazing area m ² 7.29	Average global radiation kWh/(m ² a) 133
North	107	0.63	0.95	0.85	0.60	0.65	0.31	12.2	6.27	7.29	133
East	225	1.00	0.95	0.85	0.00	0.00	0.00	0.0	0.00	0.00	225
South	414	0.95	0.95	0.85	0.59	0.65	0.45	9.6	6.26	5.65	385
West	248	1.00	0.95	0.85	0.00	0.00	0.00	0.0	0.00	0.00	248
Horizontal	347	1.00	0.95	0.85	0.00	0.00	0.00	0.0	0.00	0.00	347
Total or average value for all windows.						0.65	0.37	21.74	6.27	12.94	243

Frame absorptivity

0.25

Frame emissivity

0.90

Figure 16 - Building J Summary of Windows

	Transmiss ion losses heating period kWh/a	gains solar radiation heating kWh/a
North	6630	937
East	0	0
South	5226	2403
West	0	0
Horizontal	0	0
Total	11856	3340

Heating degree hours [kKh/a]: 87

Figure 17 - Building J Losses During the Heating Period and Solar Gains

4.2.7 Shading

Figure 18 below demonstrates reduction factors from each orientation, following the addition of the shading factor of each glazed area. The North and South sides acquire the highest shading, based on the orientation of the building and the surrounding environment. With the sun rising in the South-East during winter months, the front of the building will receive some shading early in the day, followed by the rear and West side of the building achieving shading for most of the day. No adjacent buildings have an impact on shading on Building J.

Orientation	Glazing area [m ²]	Reduction factor winter r _s	Reduction factor cooling r _{s,1}	Reduction factor cooling load r _{s,2}	Solar load [kWh/(m ² Glazinga)]
North	7.29	63%	68%	68%	146
East	0.00	100%	100%	100%	0
South	5.65	95%	96%	96%	453
West	0.00	100%	100%	100%	0
Horizontal	0.00	100%	100%	100%	0

Figure 18 - Building J Summary of Shading

4.2.8 Ventilation

With natural ventilation only being assumed due to the in-line Mechanical Ventilation Heat Recovery (MVHR) units not fully operational, an air test carried out on Building J provided an air volume of 797m³, and an air

change rate of 12.54 per hour. A high air permeability value of 11.41m³/hm² was recorded, demonstrating that the building is losing a high amount of air, with high energy wasted from heat losses, making the building in-efficient.

Air permeability	qE50	11.41	m ³ /(hm ²)
Excess extract air		For annual demand: 0.00	For heating load: 0.00 1/h
Infiltration air change rate	n _{V,Rest}	0.878	2.195 1/h

Figure 19 - Building J Air Permeability and Infiltration Air Change Rate

Results

Average airflow rate	Average air change rate heating period	Excess air (extract air system)	Effective heat recovery efficiency	Humidity recovery efficiency	Effective heat recovery efficiency, cooling	Humidity recovery efficiency	Specific electric efficiency	SHX Heat recovery efficiency
m ³ /h	1/h	1/h	[-]	[-]	[-]	[-]	Wh/m ³	[-]
692	0.87	0.00	0.0%	N/A	0.0%	N/A	0.00	0.0%

Figure 20 - Building J Summary of Ventilation

4.2.9 Domestic Hot Water (DHW) & Distribution

The heat delivery was inputted as radiators, with further detail on pipework delivery length, thickness, insulation and thermal conductivity. There is no cooling available in Building J, therefore this was discarded. Figure 21 shows the losses through the heating distribution and Domestic Hot Water (DHW) system, given the poor insulation and length of pipework on the flow and return. Annually, around 32,000kWh is lost through distribution of DHW.

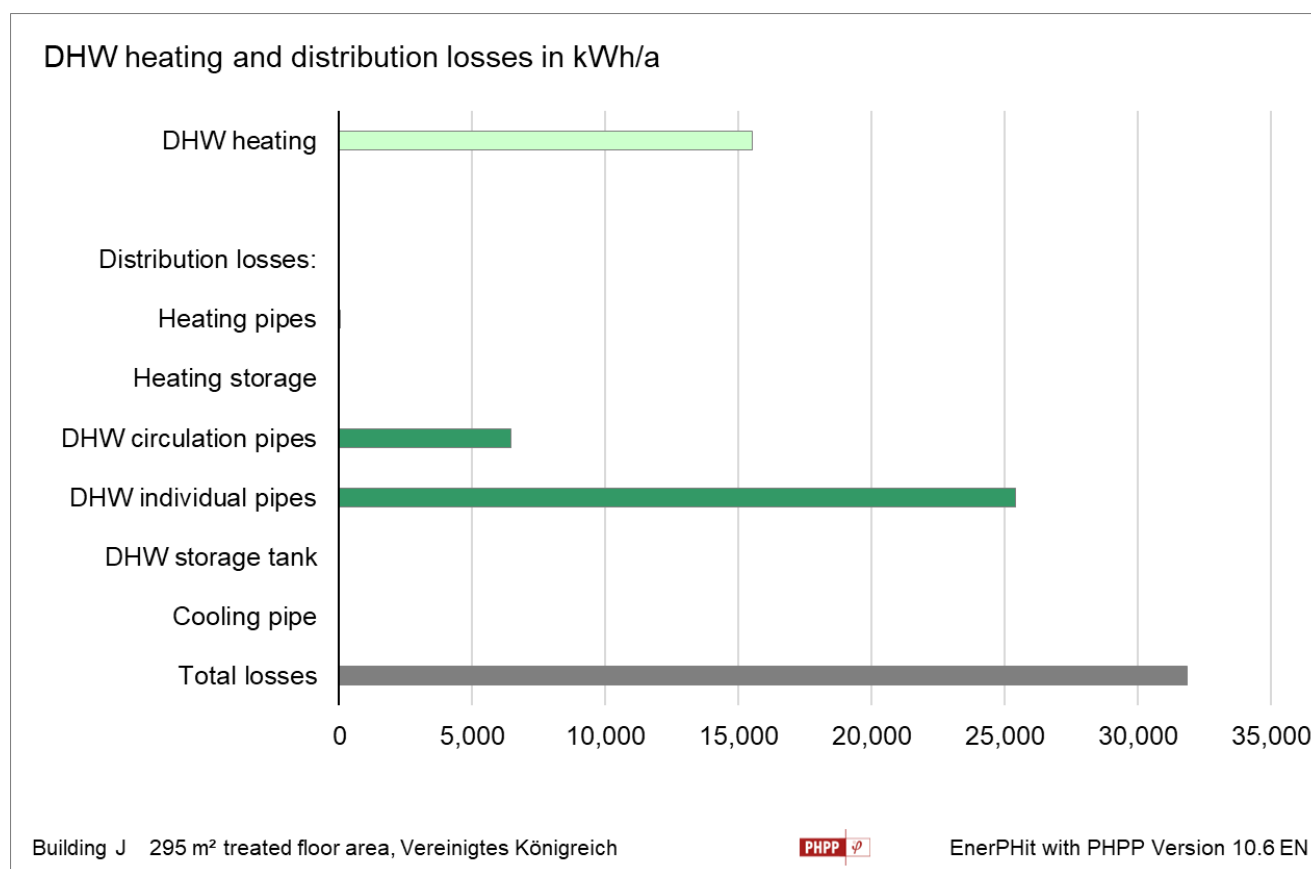


Figure 21 - Building J Heating and Distribution Losses of DHW

4.2.10 Primary Energy Renewables (PER)

Figure 22 demonstrates a visual aid to ensure that the energy demand of Building J can align with renewable energy production. It is clear to see that renewable energy sources could be used for Building J, with an annual demand of $330 \text{ kWh}/(\text{m}^2_{\text{TFA}})$, however, this further highlights the inefficiencies of Building J, where further improvements could be made to reduce the demand for PER.

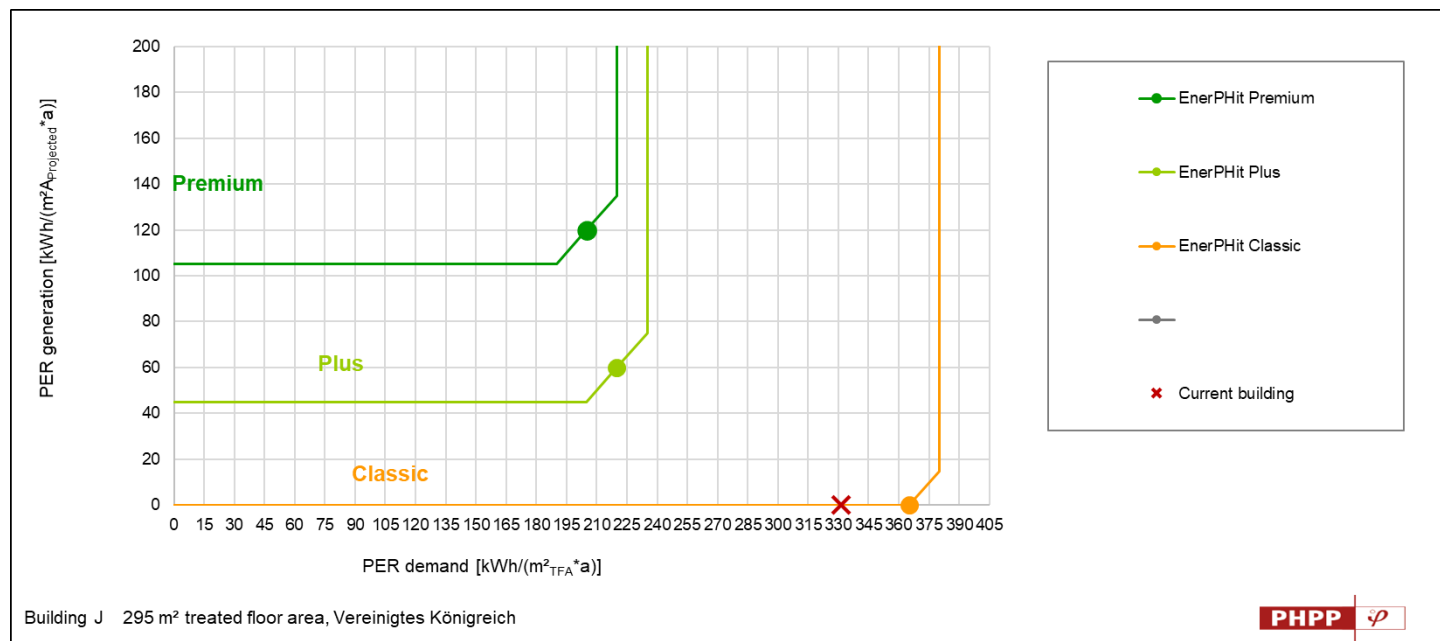


Figure 22 - Building J PER Compliance with PHPP

4.2.11 Annual & Monthly Heating

From the inputted data, Figure 23 presents the annual heat losses and gains of Building J. It is clear to see that there are in-efficiencies with the installed windows, losing significant heat, $30.8 \text{ kWh}/(\text{m}^2 \cdot \text{a})$. This is also a contributing factor to the ventilation losses, followed by gaps around doors and the structure where a total of $104 \text{ kWh}/(\text{m}^2 \cdot \text{a})$ is lost. With this, the heating demand of the building is extremely high, to keep the building warm with the amount of heat lost. There is very little solar gain from the windows, and internal gains are also low from lights, computers and other appliances. Similarly, Figure 24 shows the heat losses and gains of Building J, over a month. Monthly figures are slightly higher than the annual, however this is due to the monthly method being steady-state, and not accurately model all months of the year, disregarding seasonal effects.

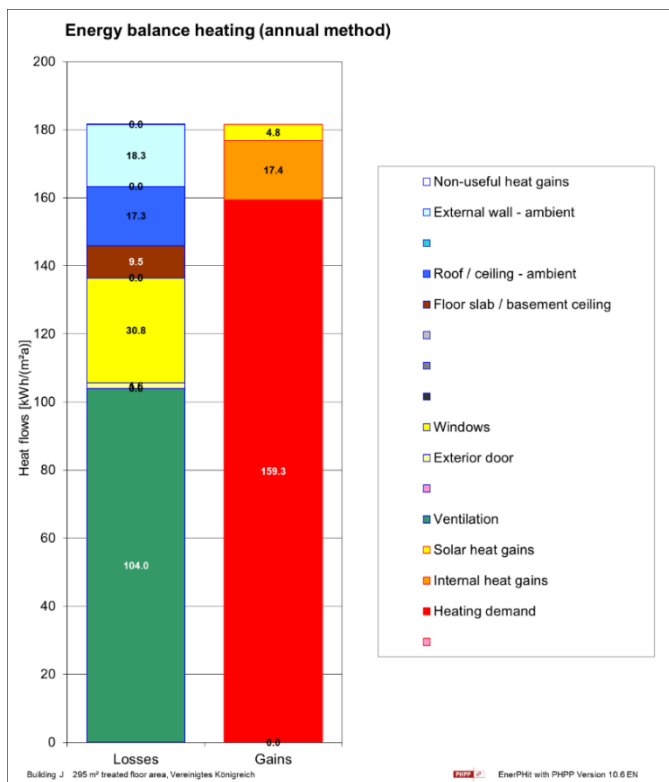


Figure 23 - Building J Annual Energy Balance

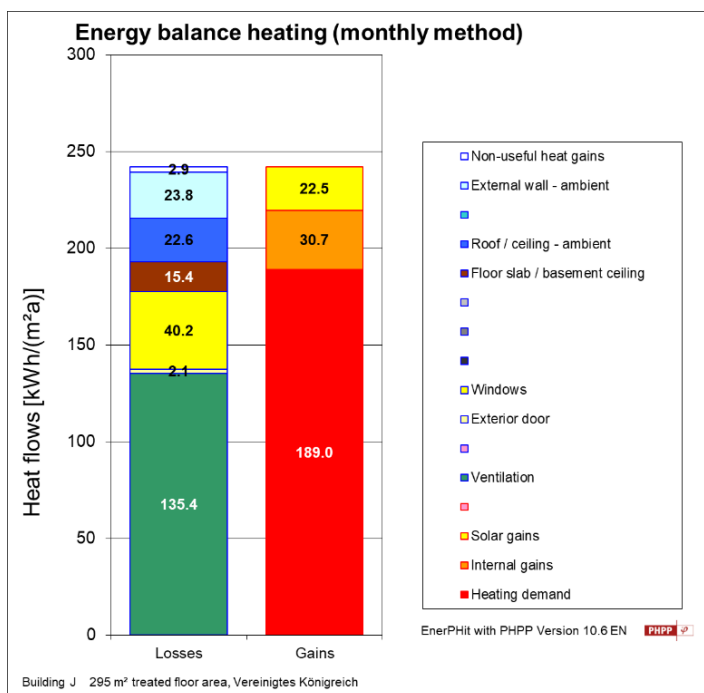


Figure 24 - Building J Monthly Energy Balance

Figure 25 further expands on Figures 23 & 24, showing the losses and gains projected over a 12-month period. There is a clear demonstration that the building inefficiencies have a significant impact, with heating demand of the building being very high, especially in the winter months, and do not equal the gains. This again shows that the heating source is working extremely hard to keep the building warm, given the loss of heat.

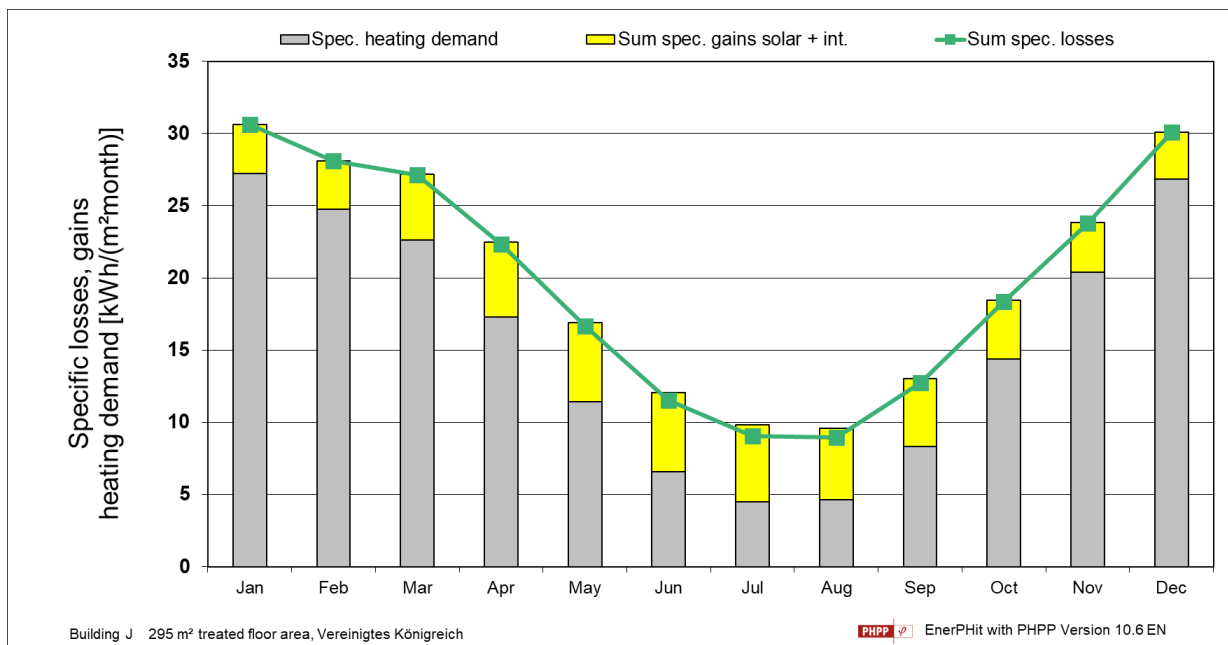


Figure 25 - Building J Projected Monthly Heating Demand, Solar Gain and Losses

4.3 Actual Gas & Electricity Consumption of Building J

4.3.1 Gas

Gas meter readings were taken from Building J, over a period from April 2024 to March 2025. Meter readings were taken every half-hour, on each day, therefore a total of 48 readings per day. Total gas usage was calculated per day and then were totalled per month. Table 3 below shows the total gas consumption of Building J between April 2024 and March 2025, along with the cost per kWh. Overall, Building J had a bill of £8,400.73 for the gas usage alone. December 2024 to March 2025 were the most expensive months, with heating demand at its highest.

Table 3 - Building J Gas Consumption and Cost Between April 2024 and March 2025

Current Gas Cost			
Month	Total Consumption (kWh)	Price (per kWh)	Total Price
Apr-24	21,287.99	£0.03	£638.64
May-24	9,787.80	£0.02	£235.89
Jun-24	6,153.64	£0.03	£160.61
Jul-24	7,571.48	£0.03	£192.69
Aug-24	7,048.92	£0.03	£208.44
Sep-24	7,626.90	£0.04	£301.26
Oct-24	1,5271.45	£0.03	£525.34
Nov-24	28,018.31	£0.03	£912.84
Dec-24	31,743.51	£0.04	£1,244.35
Jan-25	34,527.03	£0.05	£1,581.34
Feb-25	30,843.21	£0.04	£1,378.69
Mar-25	31,308.28	£0.03	£1,020.65
			£8,400.73

As expected, gas consumption is at its highest between the months of October and April, due to the colder climate of the Autumn and Winter. The highest gas consumption can be seen in January 2025, at 35,000kWh. There is still a requirement for gas during the Spring and Summer with hot water remaining a significant building service. With weather conditions still slightly cooler in April 2024, the requirement for space heating was not necessary, up until after September 2024. An average of 7,637kWh of gas was used between May 2024 to September 2024, whereas between October 2024 to March 2025, the average gas usage was 27,571kWh. Figure 26 shows the total gas consumption of Building J, whereas Figure 27 presents the data of gas consumption from the boilers, and gas consumption from the HWS generator. It is assumed during the summer months; the gas consumption is solely for the HWS generator. Appendix C shows further detail on the gas consumption of Building J between April 2024 and March 2025. With this, no heating demand was required for the months of June 2024 to September 2024, with only the DHW demand on the building. Table 4 further shows the share of gas consumption from the boilers and the hot water cylinder, where it reports the running cost of each generator each month, with the pattern aligning with the consumption data.

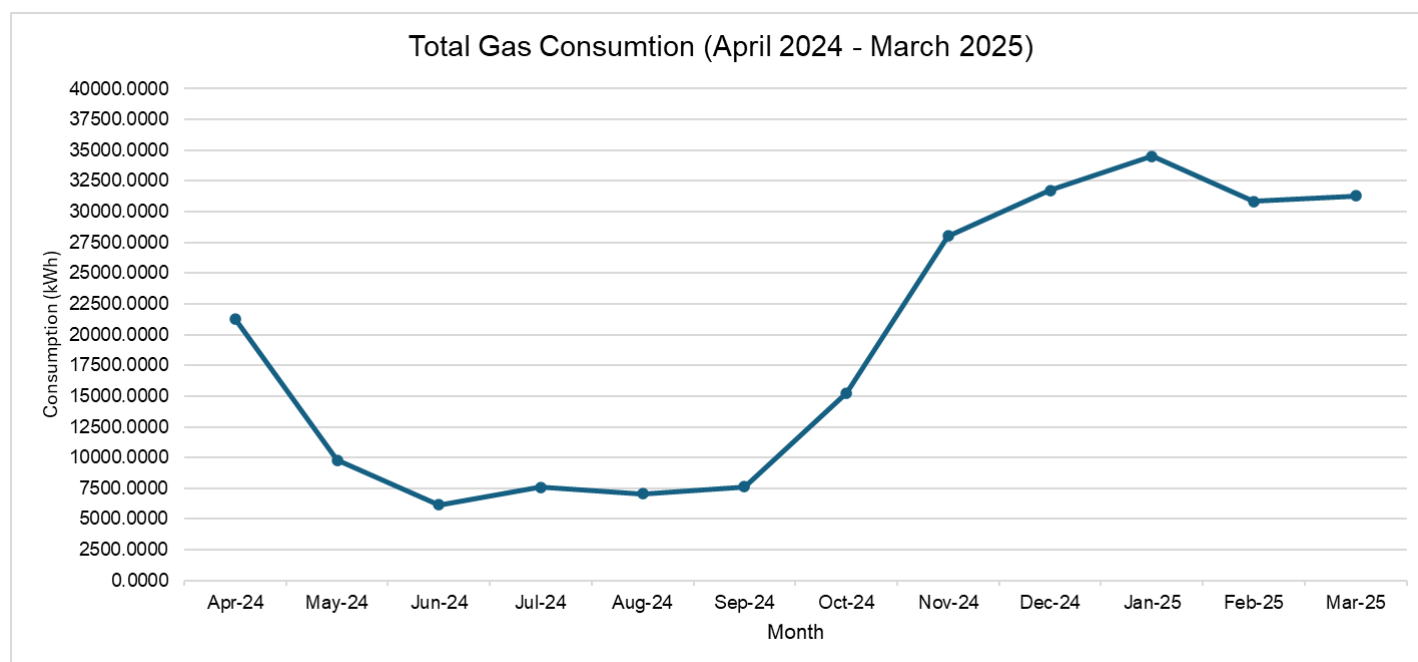


Figure 26 - Building J Current Total Gas Consumption between April 2024 to March 2025

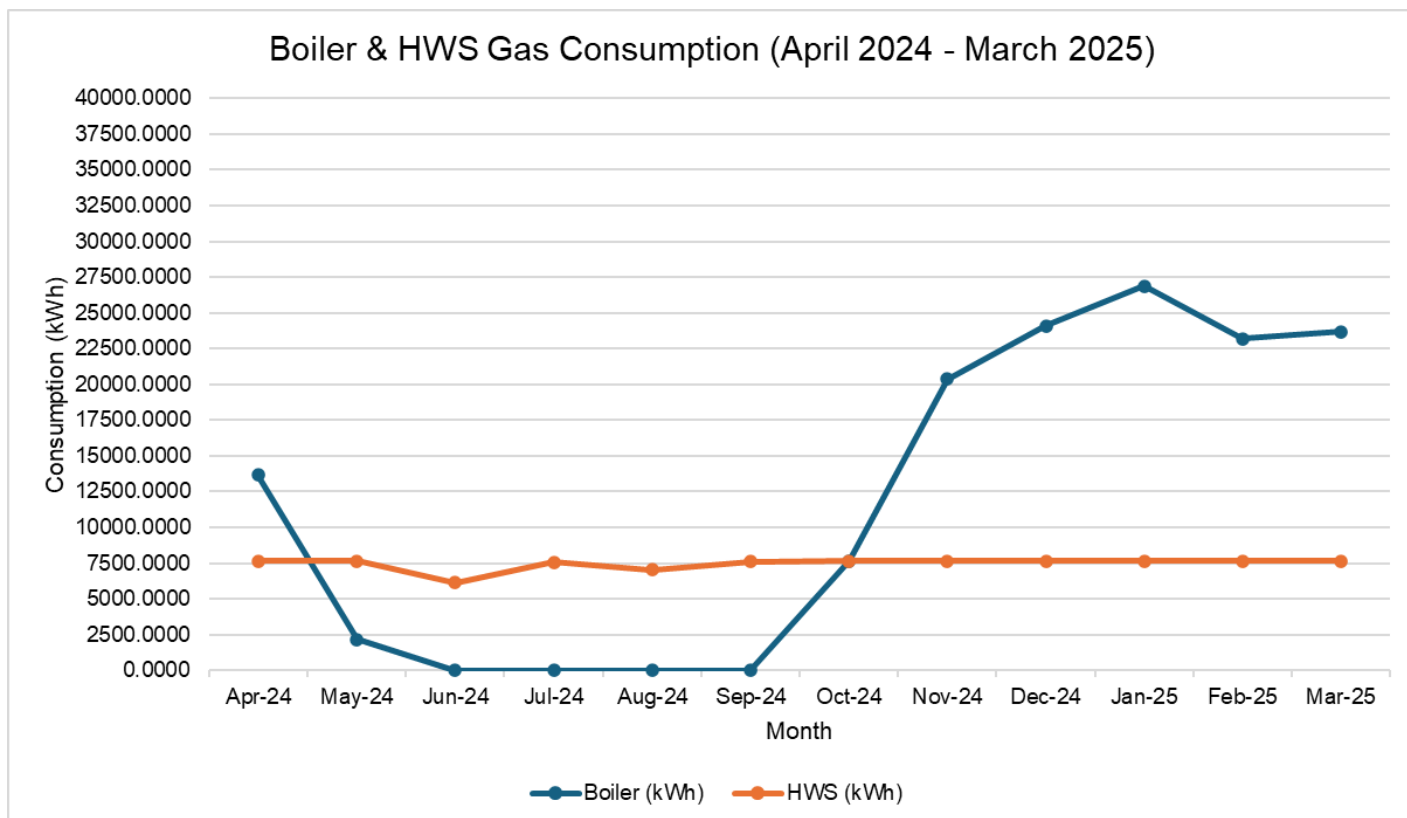


Figure 27 - Building J Boiler and Hot Water Cylinder Gas Consumption Between April 2024 to March 2025

Table 4 - Building J Gas Consumption and Cost of Boiler and Hot Water Cylinder

Boiler & Hot Water Cylinder Gas Consumption						
Month	Cost per kWh	Boiler (kWh)	Boiler Running Cost	HWS (kWh)	Hot Water Cylinder Running Cost	Total Cost
Apr-24	£0.03	13,650.25	£409.51	7,637.75	£229.13	£638.64
May-24	£0.02	2,150.05	£51.82	7,637.75	£184.07	£235.89
Jun-24	£0.03	0.0000	£0.00	6,153.64	£160.61	£160.61
Jul-24	£0.03	0.0000	£0.00	7,571.48	£192.69	£192.69
Aug-24	£0.03	0.0000	£0.00	7,048.92	£208.44	£208.44
Sep-24	£0.04	0.0000	£0.00	7,626.90	£301.26	£301.26
Oct-24	£0.03	7,633.70	£262.60	7,637.75	£262.74	£525.34
Nov-24	£0.03	20,380.56	£664.00	7,637.75	£248.84	£912.84
Dec-24	£0.04	24,105.76	£944.95	7,637.75	£299.40	£1,244.35
Jan-25	£0.05	26,889.28	£1,231.53	7,637.75	£349.81	£1,581.34
Feb-25	£0.04	23,205.46	£1,037.28	7,637.75	£341.41	£1,378.69
Mar-25	£0.03	23,670.53	£771.66	7,637.75	£248.99	£1,020.65
		141,685.59	£5,373.34	89,502.94	£3,027.39	£8,400.73

4.3.2 Electricity

Electricity consumption has also been taken from Building J, where the consumption period is consistent from April 2024 to March 2025. Again, the highest electricity consumption was expected in the Autumn and Winter months, however, there can be seen a peak in August 2024. Cooling provisions are at a higher demand during the peak of summer, with multiple fans being used with the aim of reducing temperature within the

building, plus the use of air-conditioning, lighting, computers and other equipment are in use throughout the year, with procedures and appointments at a high demand, given the small difference between each month. Table 5 demonstrates the consumption and total cost of electricity usage of Building J from the above period. Overall, the yearly bill for Building J is just under £2,000, whereas Figure 26 exhibits the electrical consumption during the chosen period.

Table 5 - Building J Electricity Consumption and Cost Between April 2024 to March 2025

Current Total Electricity Consumption				
From Date	Read Date	Total Consumption (kWh)	Price (per kWh)	Total Cost
01/04/2024	30/04/2024	1,601.42	£0.06	£90.32
01/05/2024	31/05/2024	1,404.07	£0.07	£91.55
01/06/2024	30/06/2024	1,552.86	£0.07	£115.77
01/07/2024	31/07/2024	1,894.11	£0.07	£130.25
01/08/2024	31/08/2024	2,259.20	£0.08	£183.24
01/09/2024	30/09/2024	2,018.55	£0.08	£156.60
01/10/2024	31/10/2024	2,169.76	£0.09	£187.46
01/11/2024	30/11/2024	2,197.42	£0.09	£197.60
01/12/2024	31/12/2024	2,351.75	£0.10	£232.21
01/01/2025	31/01/2025	2,280.83	£0.09	£213.15
01/02/2025	28/02/2025	1,995.65	£0.11	£225.21
01/03/2025	31/03/2025	1,909.47	£0.08	£159.37
		23,635.09		£1,982.73

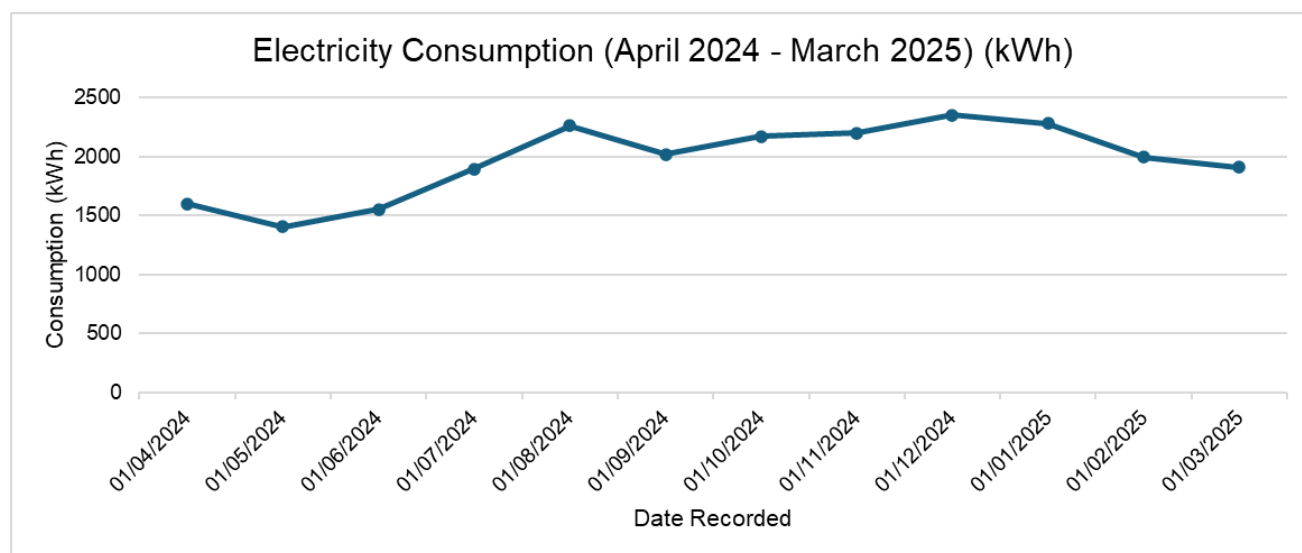


Figure 28 - Building J Electricity Consumption Between April 2024 to March 2025

With this, Table 6 shows the consumption only from the gas boilers, and the hot water cylinder. The gas boilers have a maximum output rating of 82.7kW, and there are two boilers installed in Building J. It has been assumed that peak demand is between October 2024 to February 2025, where both boilers have assumed to be in use, whereas for April and May 2024, and March 2025, the load has been spread over both boilers, with half the demand. The boilers are assumed not to be in operation between June 2024 to September 2024. Gas boilers are also assumed to run for around 10 hours a day. With regards to the hot water cylinder, the

heat input rating is 0.03kW. There is a consistent demand assumed for hot water across between April 2024 and March 2025, with demand being reliant on the number of days within the calendar month.

Between April 2024 and March 2025, it cost £965.76 to run the gas boilers, with the cost of hot water generation and usage being £216.03. Overall, this cost £1,181.80. From Table 5 above, £800.93 is spent on other electrical demands, therefore, 59% of Building J's electricity demand is used on space heating and hot water generation.

Table 6 - Building J Electricity Consumption and Cost of Boiler and Hot Water Cylinder

Boiler, Hot Water Cylinder and Other Electricity Consumption									
From Date	Read Date	Price per kWh	Boiler (kWh)	Boiler Cost	Hot Water Cylinder (kWh)	Hot Water Cylinder Cost	Other Electricity Consumption (kWh)	Cost	Total Cost
01/04/2024	30/04/2024	£0.06	827.00	£46.64	216.00	£12.18	558.42	£31.49	£90.32
01/05/2024	31/05/2024	£0.07	827.00	£53.92	223.20	£14.55	353.87	£23.07	£91.55
01/06/2024	30/06/2024	£0.07	0.00	£0.00	216.00	£16.10	1336.86	£99.66	£115.77
01/07/2024	31/07/2024	£0.07	0.00	£0.00	223.20	£15.35	1670.91	£114.90	£130.25
01/08/2024	31/08/2024	£0.08	0.00	£0.00	223.20	£18.10	2036	£165.14	£183.24
01/09/2024	30/09/2024	£0.08	0.00	£0.00	216.00	£16.76	1802.55	£139.84	£156.60
01/10/2024	31/10/2024	£0.09	1654.00	£142.90	223.20	£19.28	292.56	£25.28	£187.46
01/11/2024	30/11/2024	£0.09	1654.00	£148.73	216.00	£19.42	327.42	£29.44	£197.60
01/12/2024	31/12/2024	£0.10	1654.00	£163.32	223.20	£22.04	474.55	£46.86	£232.21
01/01/2025	31/01/2025	£0.09	1654.00	£154.57	223.20	£20.86	403.63	£37.72	£213.15
01/02/2025	28/02/2025	£0.11	1654.00	£186.65	201.60	£22.75	140.05	£15.80	£225.21
01/03/2025	31/03/2025	£0.08	827.00	£69.03	223.20	£18.63	859.27	£71.72	£159.37
			10751.00	£965.76	2628.00	£216.03	10256.09	£800.93	£1,982.73

Figure 29 shows the electricity consumption of the boilers, hot water cylinder and other electricity requirements for Building J. The consumption of the hot water cylinder is minimal to the overall consumption, around 10% of the overall consumption. The gas boilers peak during the winter months, and overshadow the residual requirement for electricity, whereas in the summer months, this role is reversed due to cooling demands.

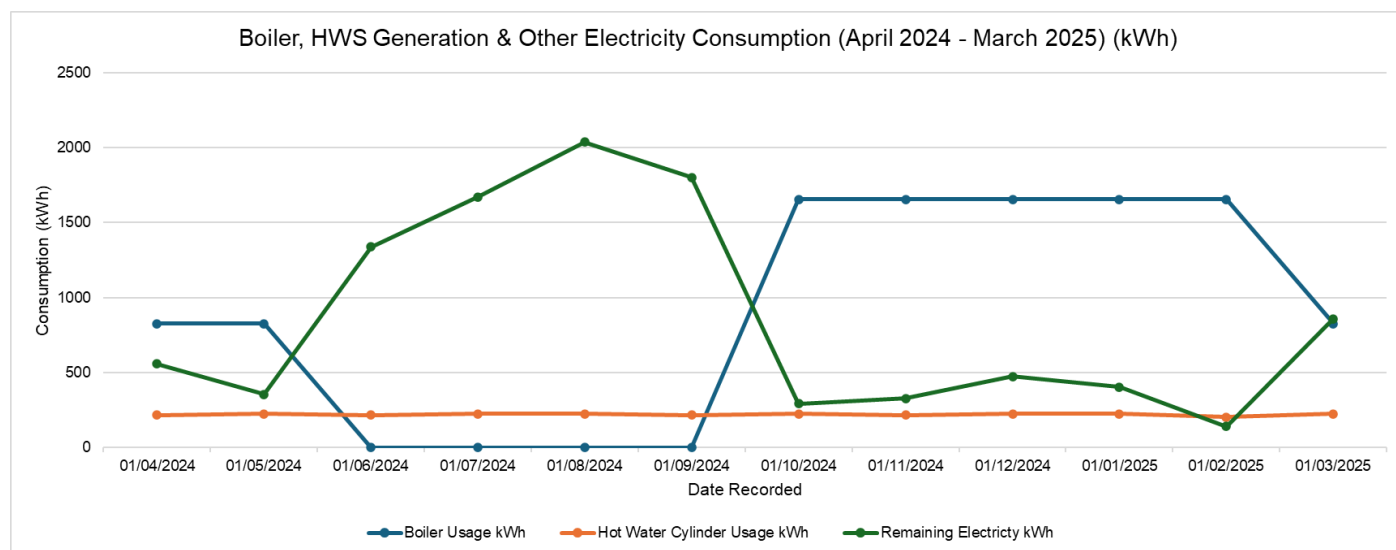


Figure 29 - Building J Boiler, Hot Water Cylinder & Other Electricity Consumption Between April 2024 to March 2025

4.4 Energy Efficiency Improvement

4.4.1 Air Source Heat Pump (ASHP)

With a view of improving energy efficiency of Building J, following extensive research, installing an ASHP has emerged as an option. Appendix A.21 & A.22 show the current heat & hot water source. It is clear to see that there are separate sources for each requirement, therefore, given this is a theoretical concept, adverse effects or unexpected issues can be spotted early and managed before being implemented throughout the building, and potentially to other healthcare facilities, therefore an ASHP will be conceptualised for the heating only.

For the total peak demand of Building J, the maximum heating load multiplied by the TFA is required, which can be seen below.

$$\text{Max Heating Load} \times \text{TFA} = \text{Total Peak Demand}$$

$$80 \text{ W/m}^2 \times 295.21 \text{ m}^2 = 23616.80$$

$$\frac{23616.8}{1000} = 23.6168 \text{ kW}$$

Equation 1 - Total Peak Demand of Building J (Feist et al., 2022)

From this equation, an ASHP with above 24kW capacity is required for Building J, which is considered a larger ASHP size. Further to this, it has been decided that a cascade system is to be installed, with three 10kW Grant Aeronas³ R32 ASHPs to achieve above 24kW, for future resilience.



Figure 30 - Building J 3D Model & Plant Room Location (Google, 2026a)

Currently, the gas boilers and hot water cylinder are in the rear Plant Room which can be seen in Figure 30 above. With the removal of the gas boilers, there will be extended space within the Plant Room, however, the ASHP is required to be outside to obtain a high volume of ambient air, for advanced efficiency. Further to this, two possible locations can be seen in Figures 31 & 32. Both locations provide close access to the Plant Room, where new services can connect to existing, whilst also having full access to ambient air. Figure 31 will allow ASHPs to be connected to the Plant Room wall, whereas Figure 32 will see the ASHPs on the

ground. With this, a further base will have to be constructed given the uneven terrain, adding to installation costs.



Figure 31 - Option 1 ASHP Location Wall Mounted (Google, 2026a)



Figure 32 - Option 2 ASHP Location Floor Mounted (Google, 2026a)

4.4.1.1 Theoretical Gas Consumption

With three 10kW ASHPs to replace the gas heating boilers in Building J, the gas consumption shown in above in Tables 3 & 4 would alter. Given the removal of the gas boilers, any gas usage would be mitigated, however the HWS generation still requires a source of gas, therefore gas isn't completely removed. Table 7 demonstrates the theoretical gas usage following the installation of an ASHP, with costs per kWh.

Table 7 - Building J Estimated Gas Consumption and Cost Following Installation of ASHPs

Estimated Gas Cost			
Month	Hot Water Cylinder Gas Consumption (kWh)	Price (per kWh)	Total Hot Water Cylinder Running Cost
Apr-24	7,637.75	£0.03	£229.13
May-24	7,637.75	£0.02	£184.07
Jun-24	6,153.64	£0.03	£160.61
Jul-24	7,571.48	£0.03	£192.69
Aug-24	7,048.92	£0.03	£208.44
Sep-24	7,626.90	£0.04	£301.26
Oct-24	7,637.75	£0.03	£262.74
Nov-24	7,637.75	£0.03	£248.84
Dec-24	7,637.75	£0.04	£299.40
Jan-25	7,637.75	£0.05	£349.81
Feb-25	7,637.75	£0.04	£341.41
Mar-25	7,637.75	£0.03	£248.99
			£3,027.39

Subsequently to this, Figure 33 below shows the difference in gas consumption when the gas boilers and HWS generator are in operation, and when the ASHP is installed complemented by the HWS generator. It is clear to see that there is a significant saving in gas usage, with an average assumed usage of 7,637kWh on HWS generation.

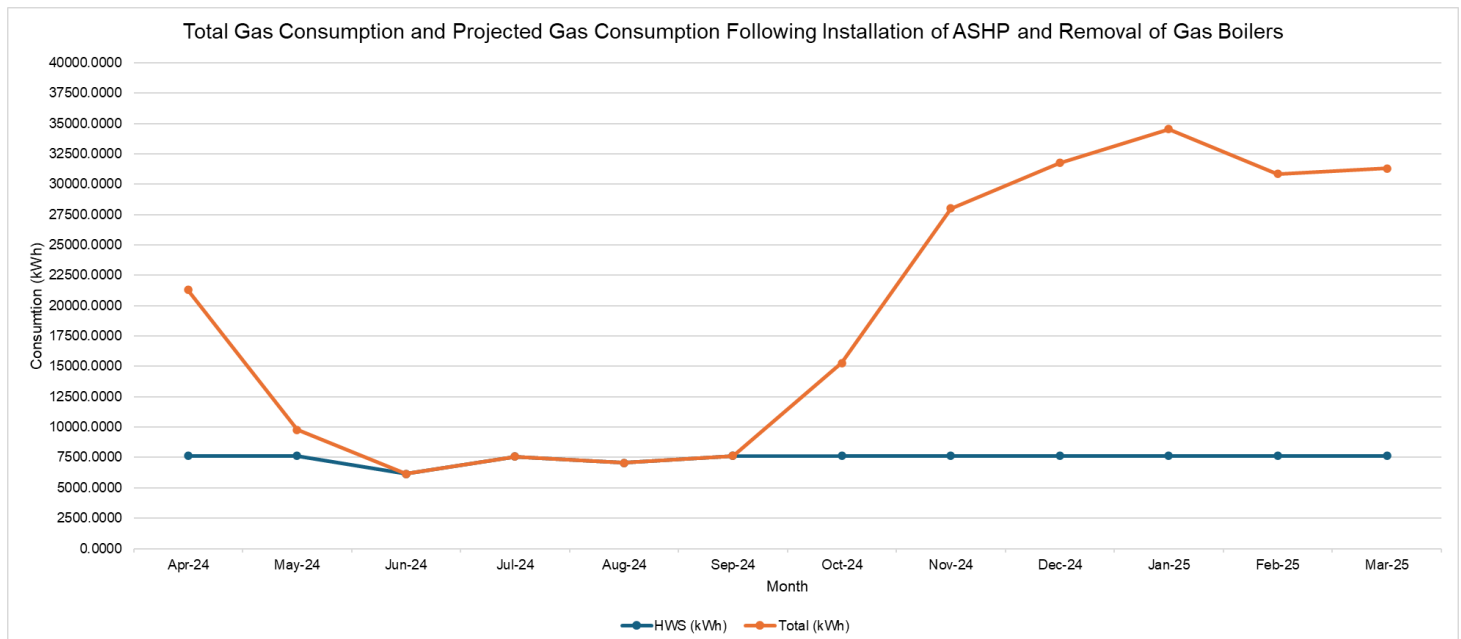


Figure 33 - Building J Current and Estimated Gas Consumption

4.4.1.2 Theoretical Electricity Consumption

With the removal of the gas boilers, the electricity consumption of three Grant AERONA³ 10kW R32 Inverter Driven ASHPs can be seen in Table 8 below. The calculations have been based on a heat loss of 23.61kW, with the full 30kW capacity not being required. The SCOP used was 3.47, from manufacturer details.

Table 8 - Building J ASHP, Hot Water Cylinder and Other Projected Electricity Consumption

ASHP, Hot Water Cylinder and Other Projected Electricity Consumption									
From Date	Read Date	Price per kWh	ASHP (kWh)	ASHP Cost	Hot Water Cylinder (kWh)	Hot Water Cylinder Cost	Other Electricity Consumption (kWh)	Other Electricity Consumption Cost	Total Cost
01/04/2024	30/04/2024	£0.06	1020.61	£57.56	216.00	£12.18	558.42	£31.49	£101.24
01/05/2024	31/05/2024	£0.07	1054.63	£68.76	223.20	£14.55	353.87	£23.07	£106.39
01/06/2024	30/06/2024	£0.07	0.00	£0.00	216.00	£16.10	1336.86	£99.66	£115.77
01/07/2024	31/07/2024	£0.07	0.00	£0.00	223.20	£15.35	1670.91	£114.90	£130.25
01/08/2024	31/08/2024	£0.08	0.00	£0.00	223.20	£18.10	2036.00	£165.14	£183.24
01/09/2024	30/09/2024	£0.08	0.00	£0.00	216.00	£16.76	1802.55	£139.84	£156.60
01/10/2024	31/10/2024	£0.09	2109.25	£182.24	223.20	£19.28	292.56	£25.28	£226.80
01/11/2024	30/11/2024	£0.09	2041.21	£183.55	216.00	£19.42	327.42	£29.44	£232.42
01/12/2024	31/12/2024	£0.10	2109.25	£208.27	223.20	£22.04	474.55	£46.86	£277.17
01/01/2025	31/01/2025	£0.09	2109.25	£197.11	223.20	£20.86	403.63	£37.72	£255.69
01/02/2025	28/02/2025	£0.11	1905.13	£214.99	201.60	£22.75	140.05	£15.80	£253.55
01/03/2025	31/03/2025	£0.08	1054.63	£88.02	223.20	£18.63	859.27	£71.72	£178.37
			13403.95	£1,200.51	2628.00	£216.03	10256.09	£800.93	£2,217.47

Figure 34 shows the overall projected electricity consumption for Building J. Following the installation of ASHPs, there has been an increase in electricity consumption. This is due to the requirement of electricity only to run the ASHPs. The pattern can be compared to the gas consumption in Figure 26 where there are peaks in the winter months due to the demand for heating.

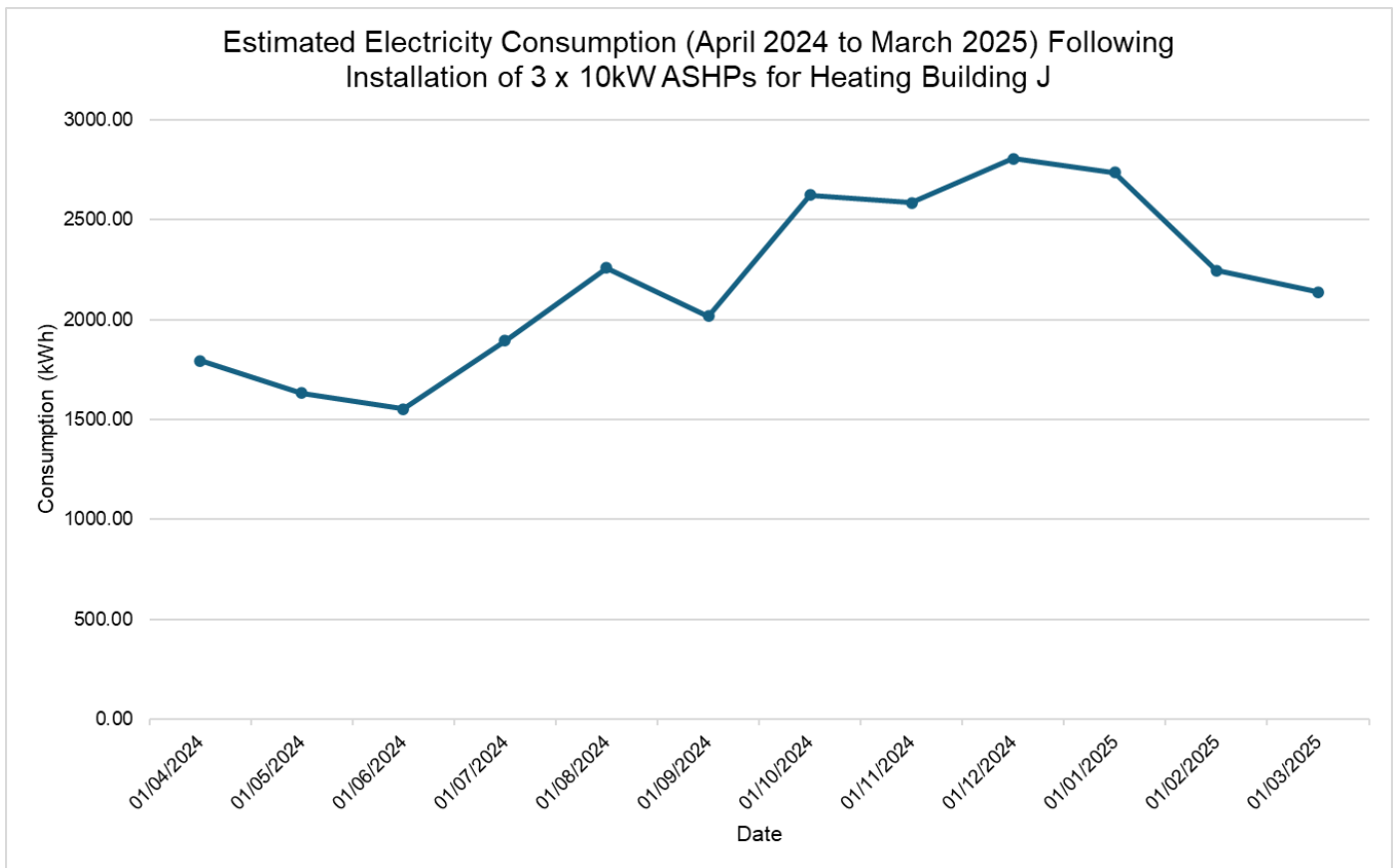


Figure 34 - Building J Projected Overall Electricity Consumption

In conjunction to this, Table 9 shows the overall estimated electricity consumption, including other electrical requirements, which have been assumed consistent, along with the hot water requirement. Like Table 8, the consumption of the ASHPs have been estimated based on the heat loss of Building J, calculated as 23.6kW. It has been assumed that during the summer months there is no requirement for the ASHP, during the spring months there will be a running period of approximately 5 hours per day, and in the winter months there would be a requirement of 10 hours of running time per day. This is based on the kWh required to run the ASHP, with the spring consumption being around half the winter consumption, and the building able to maintain temperature with the support of outdoor temperatures during the spring period.

Table 9 - Building J Projected Overall Electricity Consumption

Estimated Electricity Consumption					
From Date	Read Date	ASHP Usage (kWh)	Hot Water Cylinder Usage (kWh)	Other Electricity Demand (kWh)	Total Estimated Metered (kWh)
01/04/2024	30/04/2024	1,020.61	216.00	558.42	1,795.03
01/05/2024	31/05/2024	1,054.63	223.20	353.87	1,631.70
01/06/2024	30/06/2024	0.00	216.00	1,336.86	1,552.86
01/07/2024	31/07/2024	0.00	223.20	1,670.91	1,894.11
01/08/2024	31/08/2024	0.00	223.20	2,036.00	2,259.20
01/09/2024	30/09/2024	0.00	216.00	1,802.55	2,018.55
01/10/2024	31/10/2024	2,109.25	223.20	292.56	2,625.01
01/11/2024	30/11/2024	2,041.21	216.00	327.42	2,584.63
01/12/2024	31/12/2024	2,109.25	223.20	474.55	2,807.00
01/01/2025	31/01/2025	2,109.25	223.20	403.63	2,736.08
01/02/2025	28/02/2025	1,905.13	201.60	140.05	2,246.78
01/03/2025	31/03/2025	1,054.63	223.20	859.27	2,137.10
		13,403.95	2,628.00	10,256.09	26,288.04

Following Table 9, the shared projected consumption can be seen in Figure 35, for the ASHPs, hot water cylinder and any other electricity requirements for Building J. Similarly to Figure 29, there is a peak in demand for ASHPs during the winter months, with no demand in the summer. Hot water demand and other electrical requirements have been assumed to be consistent. There is an estimated 25% rise in electricity demand for the ASHPs, compared to the gas boilers.

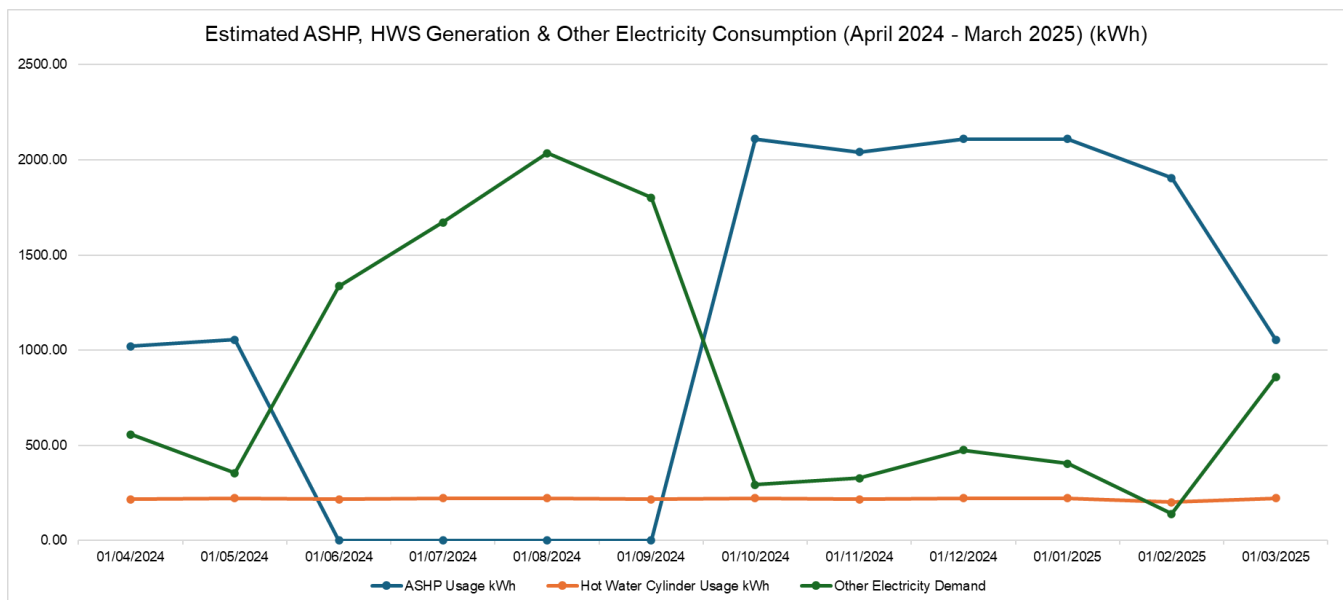


Figure 35 - Building J Projected ASHP, Hot Water Cylinder and Other Electrical Requirements (April 2024 to March 2025)

4.4.1.3 Estimated Cost Differences

Table 10 shows the estimated savings on gas consumption and electricity consumption, following the removal of the gas boilers, and replacing with an ASHP. There are no savings during the months of June 2024 to September 2024, as there was no previous demand for heating, and only hot water, which is to continue. However, overall, there is a potential saving of £5,138.59 on gas if an ASHP was installed for heat generation.

Given the increase in requirement for electricity, Building J's electricity cost will rise by 11.84%, whereas with the removal of two gas boilers, there will be a 63.96% saving on gas.

Table 10 - Building J Estimated Savings on Gas and Electricity

Estimated Savings on Gas Consumption				Estimated Savings on Electricity Consumption			Overall Savings
Month	Current Gas Cost	Estimated Gas Cost	Savings on Gas	Current Electricity Cost	Estimated Electricity Cost	Savings on Electricity	
Apr-24	£638.64	£229.13	£409.51	£90.32	£101.24	-£10.92	£398.59
May-24	£235.89	£184.07	£51.82	£91.55	£106.39	-£14.84	£36.98
Jun-24	£160.61	£160.61	£0.00	£115.77	£115.77	£0.00	£0.00
Jul-24	£192.69	£192.69	£0.00	£130.25	£130.25	£0.00	£0.00
Aug-24	£208.44	£208.44	£0.00	£183.24	£183.24	£0.00	£0.00
Sep-24	£301.26	£301.26	£0.00	£156.60	£156.60	£0.00	£0.00
Oct-24	£525.34	£262.74	£262.60	£187.46	£226.80	-£39.33	£223.27
Nov-24	£912.84	£248.84	£664.00	£197.60	£232.42	-£34.82	£629.18
Dec-24	£1,244.35	£299.40	£944.95	£232.21	£277.17	-£44.95	£900.00
Jan-25	£1,581.34	£349.81	£1,231.53	£213.15	£255.69	-£42.54	£1,188.99
Feb-25	£1,378.69	£341.41	£1,037.28	£225.21	£253.55	-£28.34	£1,008.94
Mar-25	£1,020.65	£248.99	£771.66	£159.37	£178.37	-£19.00	£752.66
	£8,400.73	£3,027.39	£5,373.34	£1,982.73	£2,217.47	-£234.75	£5,138.59

4.4.1.4 Return on Investment (ROI)

With a projected cost of £15,399.00 to purchase and install the three ASHPs, and projected savings on gas, the return on investment can be seen in Table 11. Further maintenance and servicing costs have not been considered. It would take approximately 6-years to return the invested money on the ASHP installation, with a gain of around £5,000 per year following the removal of the gas boilers.

Table 11 - Return on Investment of ASHP

Return on Investment			
Year	Investment Cost	Combined Savings	Return
Year 1	£ 15,399.00	£ 5,138.59	- £ 10,260.41
Year 2	£ 0.00	£ 5,138.59	- £ 5,121.81
Year 3	£ 0.00	£ 5,138.59	£ 16.78
Year 4	£ 0.00	£ 5,138.59	£ 5,155.37
Year 5	£ 0.00	£ 5,138.59	£ 10,293.96
Year 6	£ 0.00	£ 5,138.59	£ 15,432.56
Year 7	£ 0.00	£ 5,138.59	£ 20,571.15
Year 8	£ 0.00	£ 5,138.59	£ 25,709.74
Year 9	£ 0.00	£ 5,138.59	£ 30,848.34
Year 10	£ 0.00	£ 5,138.59	£ 35,986.93

5.0 Conclusion

With NHS decarbonisation goals and the pressing need to lower carbon emissions from healthcare facilities, this study set out to assess the technical and financial viability of replacing the current gas-fired heating system in a small NHS clinical building in South Wales with an Air Source Heat Pump (ASHP). Using a thorough PHPP energy model and a room-by-room heat loss assessment, the study has shown that construction J has substantial thermal inefficiencies, which are mostly caused by inadequate airtightness, large ventilation losses, and a subpar construction fabric.

Due to the building's high air permeability and the ventilation needs of a clinical setting, the room-by-room approach revealed significant ventilation-related heat losses, 32.58 kWh compared with 9.26 kWh through the fabric. However, because of its steady-state assumptions and failure to consider internal gains, solar gains, or dynamic thermal behaviour, this strategy similarly overstated overall heat loss. By estimating an annual heating demand of roughly 24 kWh/m² and verifying that the building's inefficiencies are caused by its modular construction, ageing envelope, and lack of mechanical heat recovery, PHPP modelling, on the other hand, offered a more comprehensive and accurate depiction of the building's performance.

Despite these drawbacks, the modelling showed that the building's peak heating load could be satisfied by a cascade system of three 10 kW ASHPs. The ASHP technology has significant financial and carbon advantages over the current gas-fired system. A 64% reduction in petrol use would result in an annual savings of £5,373.34. With an annual savings of £5,138.59, the net financial advantage is still substantial even though the operation of the ASHPs would result in an increase in electricity usage. The estimated six-year return on investment, based on installation costs of £15,399, is a compelling offer for an NHS estate facing mounting financial strain.

However, the results also show that the building's existing state limits ASHP performance. Low-temperature systems become less efficient due to high infiltration rates, inadequate insulation, and restricted solar benefits. Therefore, even though ASHPs are a good and practical choice for Building J, complementary fabric upgrades like better insulation, better glazing, and the installation of mechanical ventilation with heat recovery would greatly improve their long-term performance and cost-effectiveness.

In a broader sense, this study highlights the significance of building-specific evaluation in the design of decarbonisation initiatives throughout the NHS enterprise. A one-size-fits-all strategy is unlikely to be successful due to the variety in building typologies, ages, and construction techniques. Rather, thorough modelling, like PHPP, may give trusts the proof they need to prioritise investments, optimise system design, and steer clear of the dangers of oversizing or underperforming.

Ultimately, this study shows that even in cases when the building fabric is not ideal, ASHPs can significantly lower carbon emissions and operating expenses in older NHS buildings. Similar facilities throughout the NHS estate might achieve comparable advantages with focused investments and strategic planning, supporting the larger goal of providing a net-zero health service by 2040.

5.1 Recommendations

With this, the below provides recommendations to further improve the efficiency of Building J.

1. Improve airtightness
 - perform focused air-sealing work near windows, doors, service penetrations, and wall intersections
 - to confirm improvement, retest the airtightness
2. Install MVHR
 - Replace or repair the current MVHR units
 - Install a centralised, clinically occupancy-sized MVHR system
3. Upgrade glazing
 - Install low-U-value double or triple glazing in place of the current glazing
 - Boost the airtightness and performance of window frames
 - To balance gains and losses, consider installing solar-control glazing on south-facing elevations

4. Enhance Insulation
 - Where possible, add insulation to the walls, internally or externally
 - Increase the thickness of the roof insulation
 - Reduce ground heat loss and enhance suspended floor insulation
5. Install ASHP alongside fabric improvements
 - Install the three 10kW ASHPs in the suggested cascade
 - Ensure radiators are large enough to operate at low temperatures
 - Include sophisticated controls and weather compensation
 - During the transition, keep the gas boiler as a temporary backup (optional)
6. Apply findings across the wider NHS estate
 - Create a methodology for evaluating similar buildings that may be repeated
 - Prioritise fabric-first retrofits over the installation of heat pumps
 - Discuss results with the decarbonisation team at the Health Board to aid in strategic planning

5.2 Further Research

With the above, given additional time, the building would be re-modelled in PHPP, to determine if the efficiency has improved. Further to this, there would be extended research and work on the below.

1. Perform thorough fabric and airtightness tests
 - Use thermographic imaging to locate air leakage routes and thermal bridges
 - To verify the true level of insulation, core sampling of the roof, floors, and walls
 - Testing for airtightness both before and after corrective action
2. Verifying ASHP functionality after installation
 - SCOP, flow temperature, and compressor cycling monitoring
 - Analysing the difference between expected and actual energy usage
 - Assessing operational dependability and maintenance needs
3. Extending research to comparable NHS building stock
 - Comparing comparable structures within the health board
 - Creating a decarbonisation plan based on typologies
 - Finding the structures that provide the best return on ASHP investment
4. Investigating the integration of renewable energy and MVHR
 - Complete cost analysis of the lifecycle
 - ASHP, refrigerant, and replacement cycle embodied carbon evaluation
 - Comparing alternative technologies
 - Duct routing options
 - Limitations on noise in clinical settings
 - Operating and capital expenses
 - Effects on indoor air quality and heating demand

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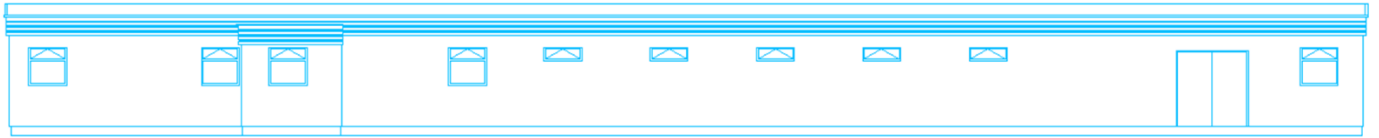
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Appendices

Appendix A – Building J Information

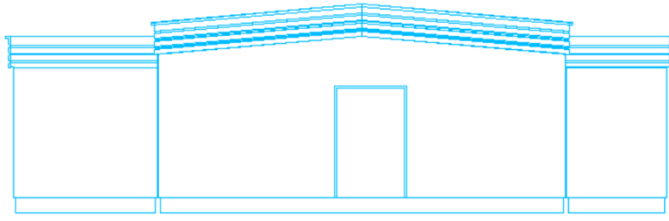
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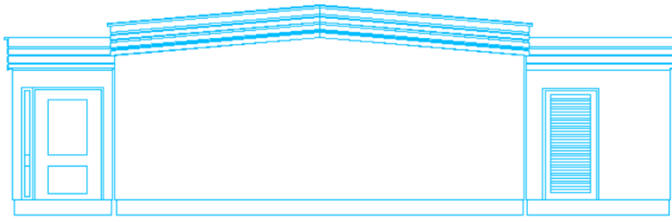
Appendix A.2 – Elevation

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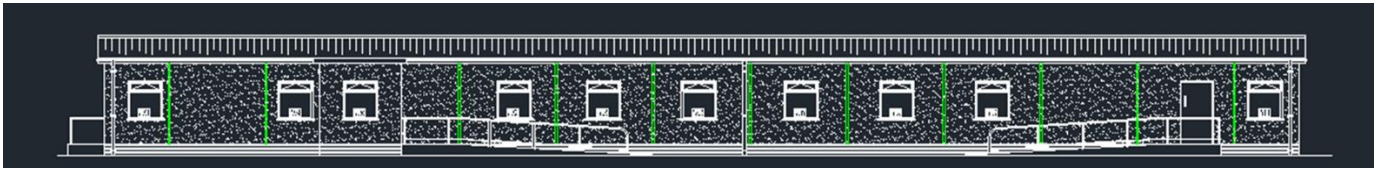
Appendix A.3 – Elevation



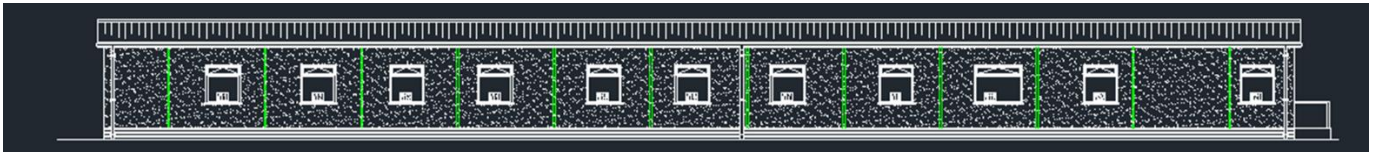
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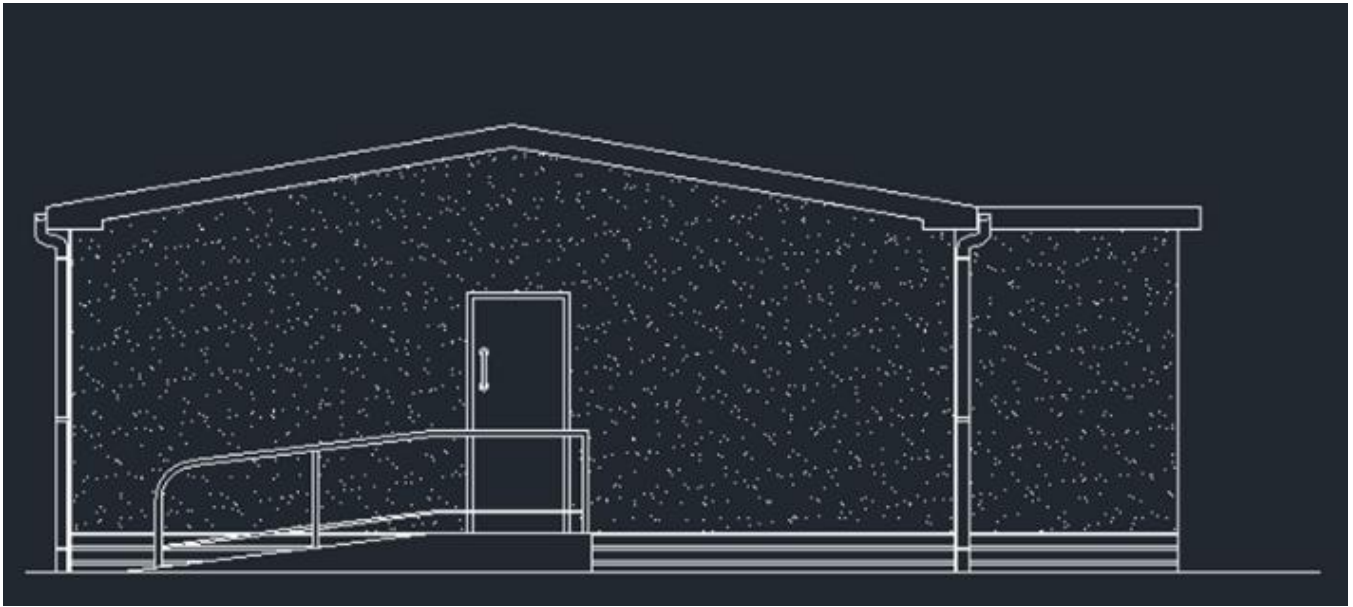
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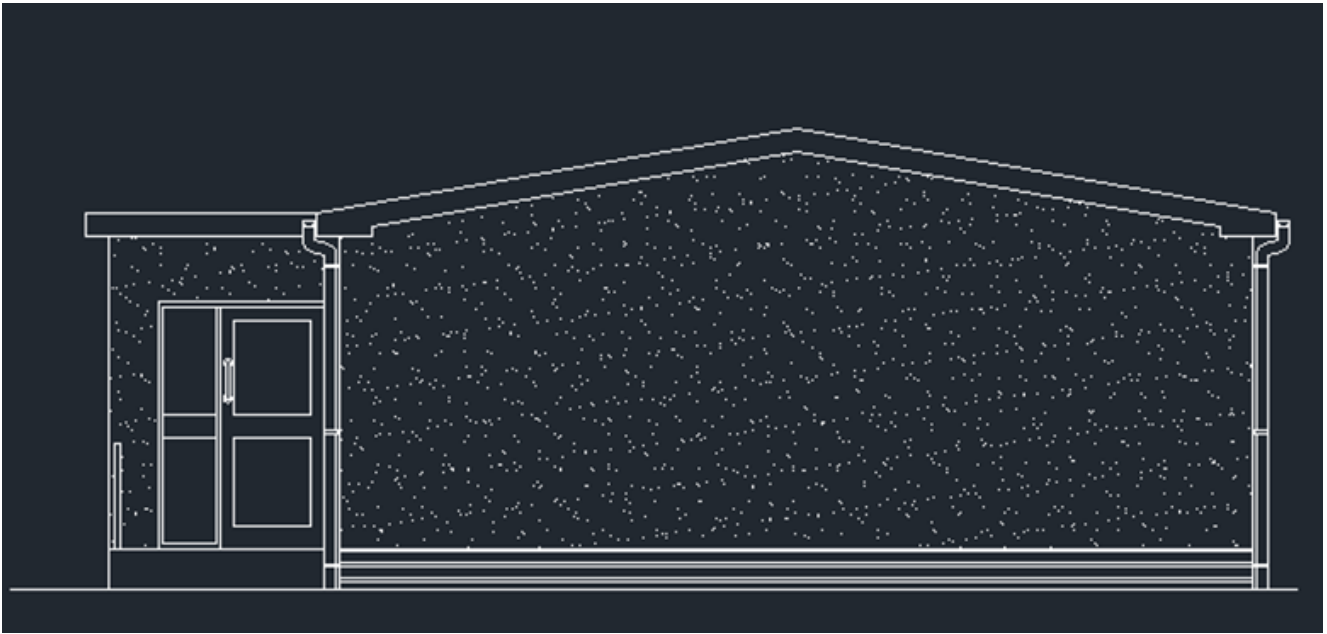
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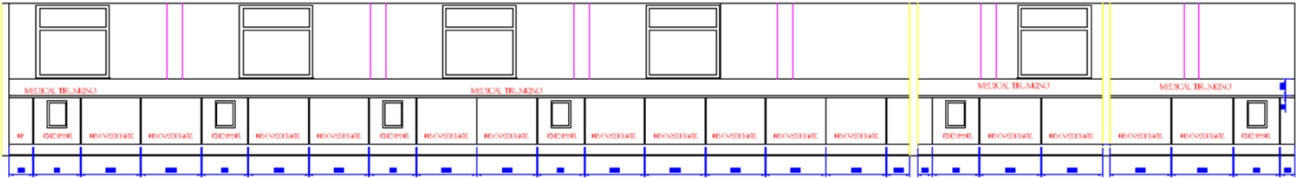
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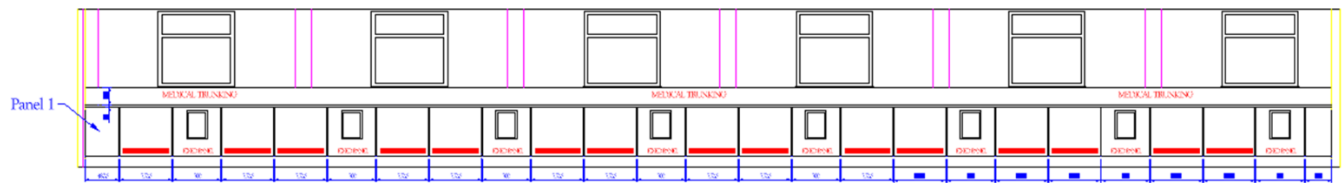
Appendix A.8 – Elevation



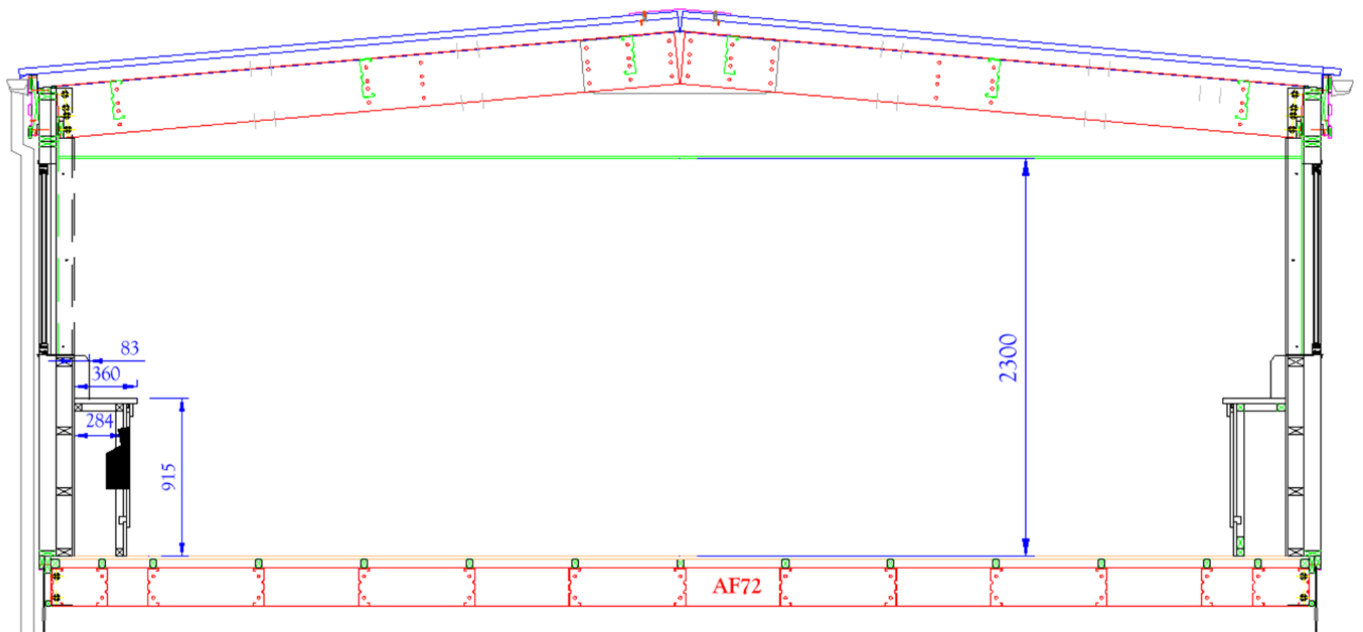
Appendix A.9 – Elevation



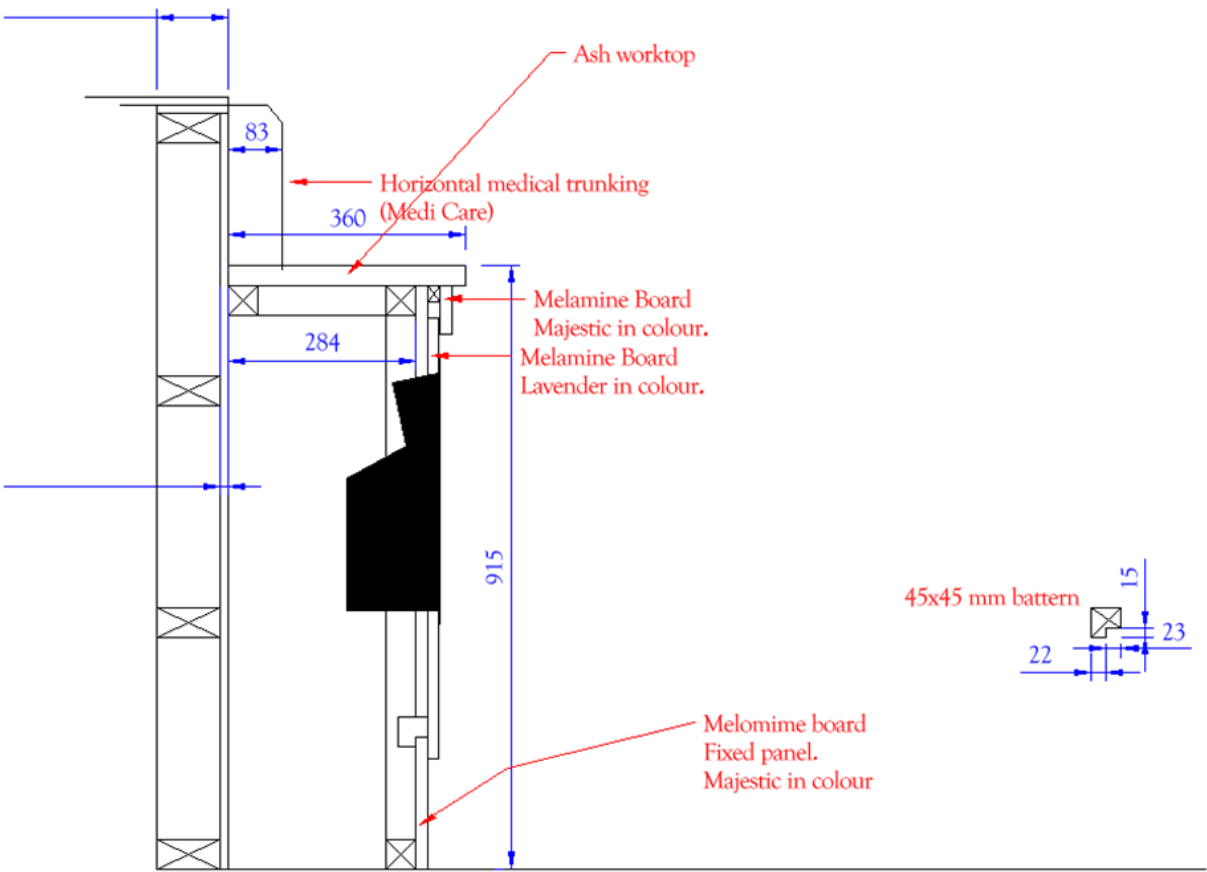
Appendix A.10 – Elevation



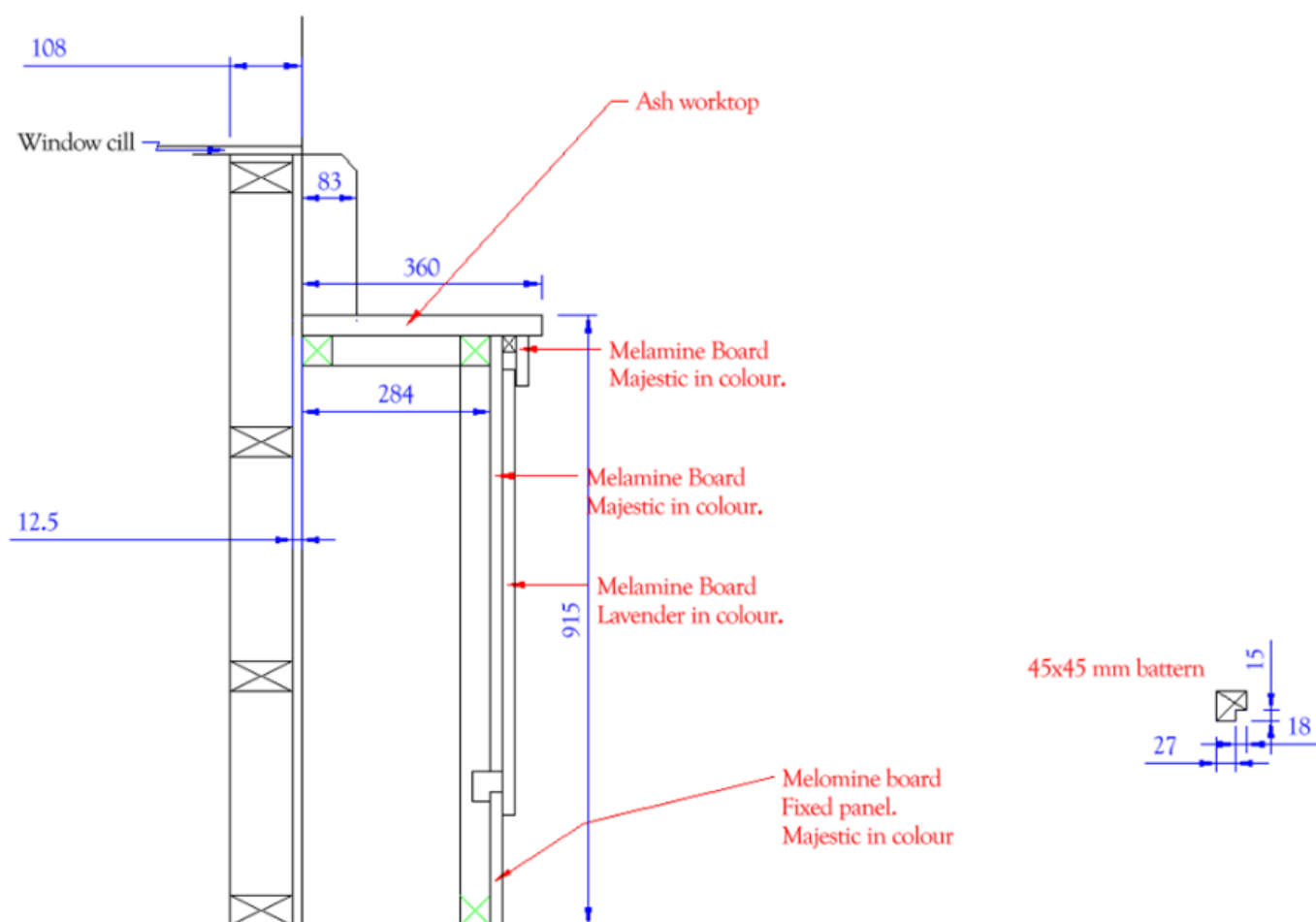
Appendix A.11 – Section Through Unit



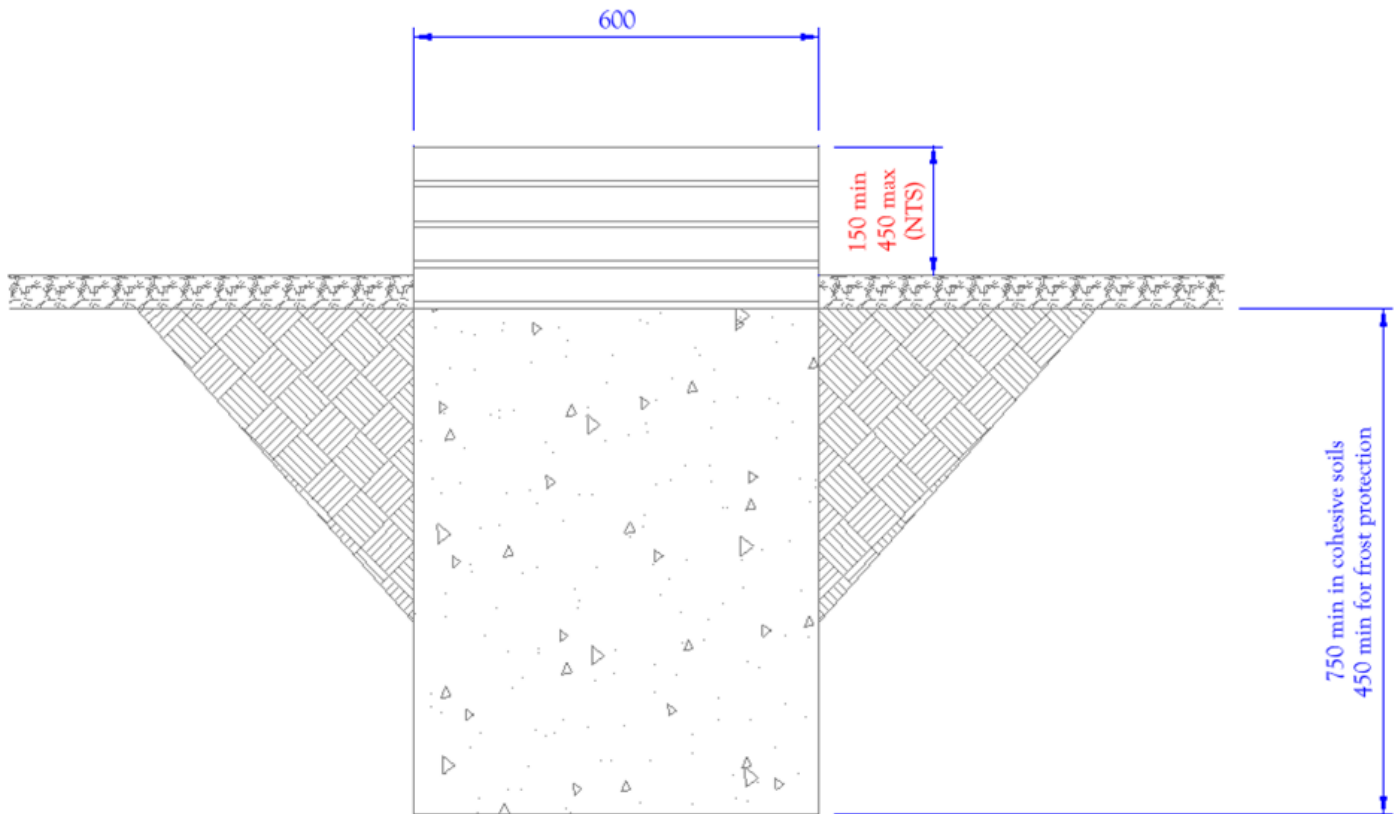
Appendix A.12 – Fixed Panel Detail



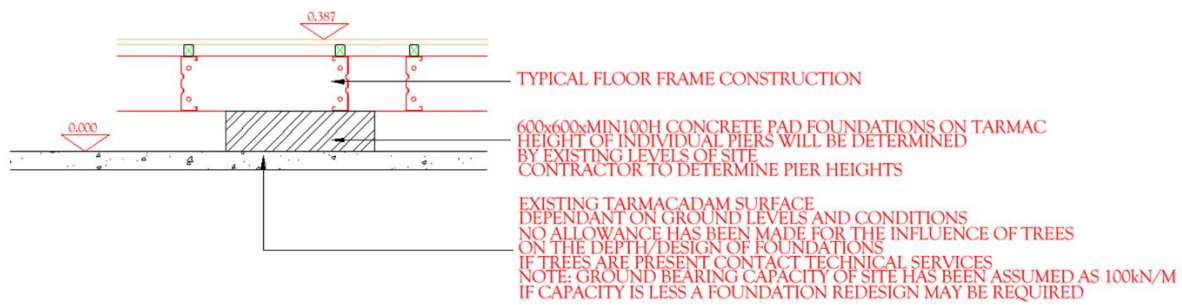
Appendix A.13 – Removable Panel Detail



Appendix A.14 – Floor Foundations Make-Up



Appendix A.15 – Floor Frame Make-Up & Section Through Foundations



Appendix A.16 – Building Make-Up

External Walls

Outer facing – Stone Aggregate Finish

Inner facing- Duplex plasterboard with a painted finish.

Core – Solid sheet insulation set into a timber frame.

U-Value – 0.35W/m²oC.

Windows

All of white UPVC construction. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable 'espagnolette' handles.

Inner reveals have UPVC angle to top side with cellular pvc cill boards.

Glazing generally will be double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.

Windows are 1100mm high x 1105mm wide with a 380mm deep vent, with a 1170mm cill height.

High level windows are 385mm high x 1105mm wide full opening vent, with a 1885mm cill height.

Roof – Flat (Warm Deck Construction)

Decking – Profile steel composite insulated sheeting.

Outer face – plastic coated steel.

Design Load – 0.60kN/m².

Slope – 5 degrees.

Gutter and pipes – Square section pvc.

Facias – Profiled Plastic coated steel.

Roof support – Galvanised steel beams and purlins.

U-Value – 0.25W/m²oC.

Floor Frame

Decking – Exterior grade plywood.

Insulation – Rigid sheet foam.

Main frame – Galvanised steel beams and cross joints.

Design load – 5kN/m².

U-Value – 0.25 W/m²oC.

External Doors

Smart Shopline Commercial quality aluminium framed doors c/w powder coat finish to a standard colour.

Non thermally broken, the doors are pivot hinged c/w anti finger trap hinge stiles, concealed overhead

closer (90 degree hold open facility is fitted as standard unless otherwise requested) and drained mobility threshold.

Main Access Door

Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle and push plate.

Secondary Access Door

A double door arrangement, nominal dimension 1800 x 2090mm. Fully panelled c/w hook type cylinder deadlock and internal thumb turn, stainless steel cranked pull handles and push plates. Panels are 28mm insulated colour coat steel or pvf2 smooth finish steel powder coated to a standard colour.

Fire Escape Door

A single door arrangement, aperture size approximately 1315mm to allow for the projection of the panic bar. Fully panelled c/w surface mounted stainless steel panic bar. Panels are 28mm insulated colour coat steel or pvf2 smooth finish steel powder coat to a standard colour.

Internal Doors

Internal door sets where specified are ½ hour fire rated, the door is a 30-minute rated fire door and the frame incorporates intumescent brush strips. Fire doors have Ryobi overhead closers. Doors are hung on 1 ½ per 100mm steel butt hinges and have SS door furniture as per door schedule.

Where specified door vision panels are 700mm high x 250mm wide, glazed pyro shield safety clear glass, offset to the handle side.

Partitions

Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.

Ceilings

Ceiling height – 2360mm using a lay in grid suspended system.

Suspended ceiling shall be Armstrong Square edge Dune tile to main area and Gyprex satin spar to W.C. area. Installed within an Armstrong Trulok XL suspension grid comprising of main runners and flush fitting cross tees forming a 600mm x 600mm membrane. Membrane runners only, will be suspended from the soffit by 2mm galvanised steel wire on 1200mm centres. The perimeter will be finished with a white aluminium capped angle trim.

Support Posts

Support posts projecting into rooms occur at 3m centres around the building perimeter.

Dependant upon roof spans, internal prop posts may also be used.

Decoration

Main body colour – Boston Brick

Roof sheeting – Goosewing Grey

Roof fascias – White

Gutters & down pipes – White

Windows – White

External doors – White

Internal wall finish – Decorated plasterboard as per finishes schedule

Ceilings – White suspended tile and grid

Skirtings, door frame & architraves – White gloss

Internal doors – Ash, self finish

Appendix A.17 – Door Details

Outward Opening. Hung On Right Hand As Viewed.	Outward Opening.	Outward Opening. Hung On Right Hand As Viewed.
Principle Entrance Door	Double Service Entrance Door	Emergency Exit Door
Minimum 2000 door set to allow frames and standard 15 handles set to connect after removal and pull handles removed. All to be fully compliant with current building regulations Part M and to be compliant with fire safety standards. To be fitted with cylinder lock dead lock external and thumbturn internal. Doors to be pivot hinged with anti-lift trap hinge system. External overhead doors with 90° hold open facility. To be double glazed with laminated glass with a 10mm gap in filled cavity.	Minimum 2000 door set to allow frames and standard 15 handles set to connect after removal and pull handles removed. All to be fully compliant with current building regulations Part M and to be compliant with fire safety standards. To be fitted with cylinder lock dead lock external and thumbturn internal. Doors to be pivot hinged with anti-lift trap hinge system. External overhead doors with 90° hold open facility. To be double glazed with laminated glass with a 10mm gap in filled cavity. To be provided inside the openings.	Minimum 2000 door set to allow frames and standard 15 handles set to connect after removal and pull handles removed. To be fitted with push and turn handle. All to be fully compliant with current building regulations Part M and to be compliant with fire safety standards. Doors to be pivot hinged with anti-lift trap hinge system. External overhead doors with 90° hold open facility. To be provided inside the openings.

Appendix A.18 – Door Schedule

Door No.	DOOR									
	SIZE		Leaf	Type	Inr/exr.	Vision Panel	Hing	Fire Res	Hinges	Lck b
	Width	Height								
001	1188	2032	Single	ALU EXCG	EXT	-	Right	FD30S	SS	-
002	PR 1025.5	2032	DOUBLE	ALU EXCG	EXT	-	NA	FD30S	SS	-
003	1233	2032	Single	ALU EXCG	EXT	-	Left	FD30S	SS	SS PANIC LATCH
004	926	1981	Single	ASH SOLID CORE	Inr	-	Left	FD30S	SS	-
005	926	1981	Single	ASH SOLID CORE	Inr	-	Right	FD30S	SS PIVOT	-
006	6100260	1981	single/half	ASH SOLID CORE	Inr	STD	Right	FD30S	SS	-
007	926	1981	Single	ASH SOLID CORE	Inr	STD	Right	FD30S	SS	-
008	926	1981	Single	ASH SOLID CORE	Inr	STD	Right	FD30S	SS	-
009	PR 926	1981	DOUBLE	ASH SOLID CORE	Inr	-	NA	FD30S	SS	-
010	926	1981	Single	ASH SOLID CORE	Inr	-	Right	FD30S	SS	-
011	926	1981	Single	ASH SOLID CORE	Inr	-	Right	FD30S	SS	-
012	6100260	1981	Single/half	ASH SOLID CORE	Inr	-	Right	FD30S	SS	-
013	926	1981	Single	ASH SOLID CORE	Inr	-	Right	FD30S	SS	-
014	6100260	1981	Single/half	ASH SOLID CORE	Inr	-	Right	FD30S	SS	-
015	6100260	1981	Single/ half	ASH SOLID CORE	Inr	-	Right	FD30S	SS	-
016	926	1981	Single	ASH SOLID CORE	Inr	-	Left	FD30S	SS	-
017	926	1981	Single	ASH SOLID CORE	Inr	-	Right	FD30S	SS	-
018	926	1981	Single	ASH SOLID CORE	Inr	-	Right	FD30S	SS	-
019	926	1981	Single	ASH SOLID CORE	Inr	-	Left	FD30S	SS	-
020	926	1981	Single	ASH SOLID CORE	Inr	-	Left	FD30S	SS	-
021	926	1981	Single	ASH SOLID CORE	Inr	-	Right	FD30S	SS	-
022	926	1981	Single	ASH SOLID CORE	Inr	STD	Right	FD30S	SS	-
023	926	1981	Single	ASH SOLID CORE	Inr	STD	Right	FD30S	SS	-

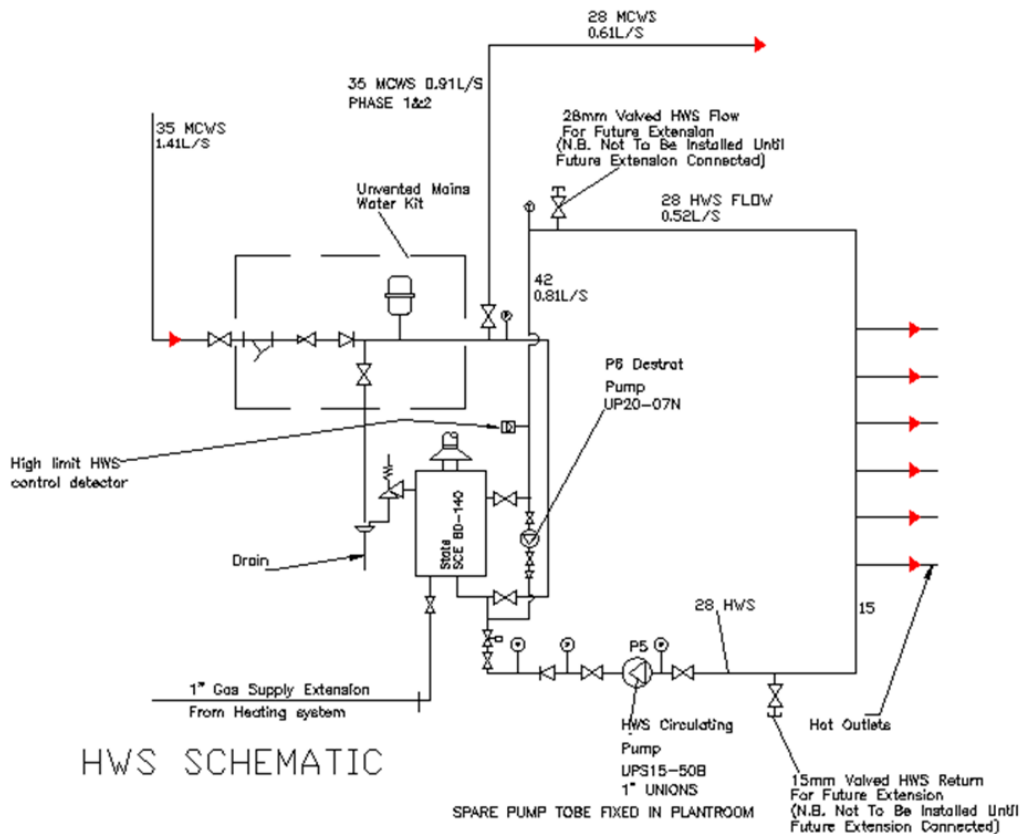
Proposed Plan.



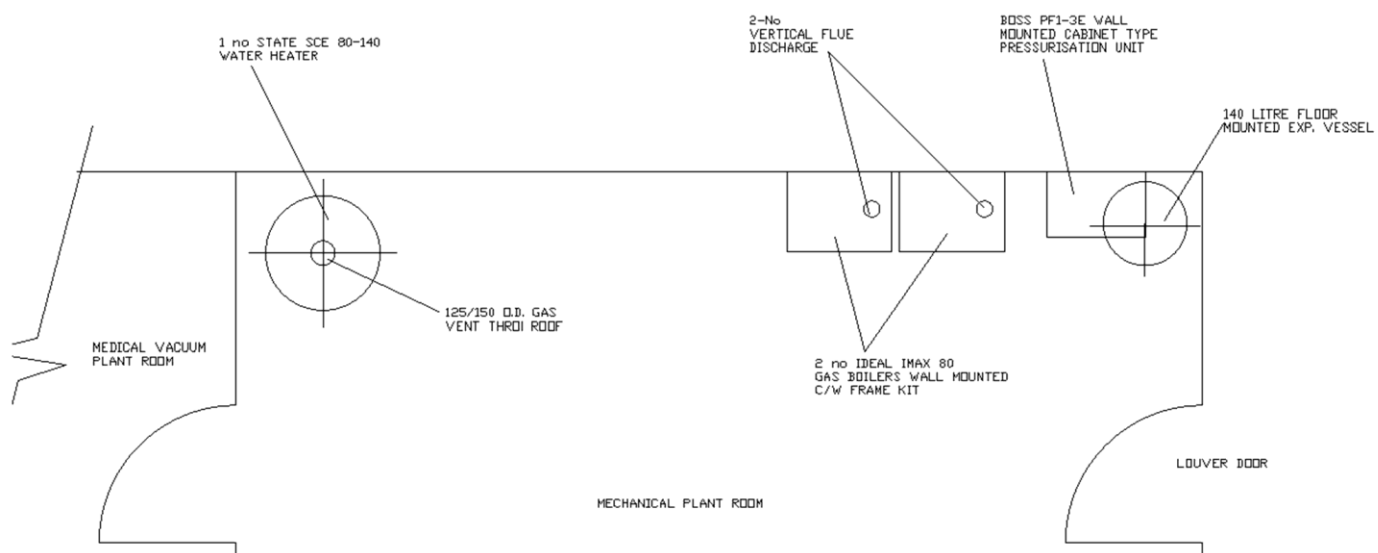
A photograph of two large, white, industrial-grade water heaters or boilers installed in a utility room. The units are mounted on a metal frame and have various pipes and valves connected to them. A red fire extinguisher is visible on the right side of the frame.



Appendix A.22 – HWS Schematic & Set Up



Appendix A.23 – Plant Room Layout



BOILER ROOM LAYOUT

Appendix B – Method 1 Room-by-Room Heat Loss Calculations

Appendix B.1 – Worksheet A Heat Losses

Worksheet A – Heat Losses																																																																																																																																											
Stage 1 - Job information																																																																																																																																											
Room 1.1		Job 1.2		Page 1.3		of 1.4																																																																																																																																					
Stage 2 - Design temperatures			Stage 3 - Ventilation heat loss																																																																																																																																								
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Appendix B.2 – Worksheet A Heat Losses Instructions

3.8.4 Worksheet A – Heat Losses – Instructions

Work through the following steps, calculating or entering data as required

Stage 1 – Job information

- 1.1 Name of the room the worksheet is for
- 1.2 Job name that the worksheet is part of
- 1.3 Page number of the worksheet
- 1.4 Total number of pages of worksheets for the job

Stage 2 – Design temperatures (see section 3.5.3)

- 2.1 Temperature that the room is being designed to be heated to (see section 3.5.3.2)
- 2.2 Outdoor temperature to which the room is being designed (see section 3.5.3.3)
- 2.3 Subtract the value in cell 2.2 from the value in cell 2.1
- 2.4 Ground reference temperature to which the room is being designed (see 'ground temperature' in section 3.5.3.3)

Stage 3 – Ventilation heat loss (see section 3.4.1)

- 3.1 Number of air changes per hour for the room (see section 3.5.4.1)
- 3.2, 3.3, 3.4 Room internal dimensions (see section 3.5.1.2)
- 3.5 Multiply values from cells 3.1, 3.2, 3.3 and 3.4
- 3.6 Typically 0.33 (see section 3.4.1)
- 3.7 Value from cell 2.3
- 3.8 Multiply values from cells 3.5, 3.6 and 3.7
- 3.9 Number of additional air changes associated with open chimneys or flues (see section 3.5.4.4)
- 3.10 Multiply values from cells 3.9, 3.2, 3.3 and 3.4
- 3.11 Typically 0.33 (see section 3.4.1)
- 3.12 Value from cell 2.3
- 3.13 Multiply values from cells 3.10, 3.11 and 3.12

Stage 4 – Fabric heat loss (see section 3.4.2)

Thermal bridging

- 4.1 If being used, the appropriate thermal bridging addition to be added to all U-values below (see section 3.5.2.6)

External walls

- 4.2, 4.3 Dimensions of external walls (see section 3.5.1.2)
- 4.4 Multiply values from cells 4.2 and 4.3
- 4.5, 4.6 Dimensions of windows (see section 3.5.1.2)
- 4.7 Multiply values from cells 4.5 and 4.6
- 4.8 U-value for windows (see section 3.5.2 and Table 3.20; and section 3.5.2.6 if allowing for thermal bridging)
- 4.9 Value from cell 2.3

4.10	Multiply values from cells 4.7, 4.8 and 4.9
4.11, 4.12	Dimensions of external doors (see section 3.5.1.2)
4.13	Multiply values from cells 4.11 and 4.12
4.14	U-value for doors (see section 3.5.2 and Table 3.20; and section 3.5.2.6 if allowing for thermal bridging)
4.15	Value from cell 2.3
4.16	Multiply values from cells 4.13, 4.14 and 4.15
4.17	Subtract values from cells 4.7 and 4.13 from cell 4.4
4.18	U-value for external wall (see section 3.5.2 and Tables 3.13 to 3.17; and section 3.5.2.6 if allowing for thermal bridging)
4.19	Value from cell 2.3
4.20	Multiply values from cells 4.17, 4.18 and 4.19

Ceilings or roofs

4.21, 4.22	Dimensions of ceiling or roof (see section 3.5.1.2)
4.23	Multiply values from cells 4.21 and 4.22
4.24 – 4.29	If no roof glazing is present, enter 0 for all cells
4.24, 4.25	Dimensions of roof glazing (see section 3.5.1.2)
4.26	Multiply values from cells 4.24 and 4.25
4.27	U-value for roof windows (see section 3.5.2, Table 3.20 and section 3.5.2.5; and section 3.5.2.6 if allowing for thermal bridging)
4.28	Value from cell 2.3
4.29	Multiply values from cells 4.26, 4.27 and 4.28
4.30	Subtract values in cell 4.26 from cell 4.23
4.31	U-value for roof and internal floors (see section 3.5.2, Table 3.19 and Table 3.27; and section 3.5.2.6 if allowing for thermal bridging)
4.32	Value from cell 2.3 if roof. If connected to an adjoining room, subtract the value in cell 2.1 in the worksheet for the adjoining room from the value in cell 2.1 in this worksheet (see 'Adjoining rooms' within section 3.5.3.3)
4.33	Multiply values from cells 4.30, 4.31 and 4.32

Internal wall 1 and 2; party wall; other 1, 2 and 3

The procedures for the following six elements are similar. Therefore, the steps have been combined.

4.x1–4.x6	If the element is not required, enter 0 for all cells
4.x1, 4.x2	Dimensions of the element (see section 3.5.1.2)
4.x3	Multiply values from cells 4.x1 and 4.x2
4.x4	U-value for appropriate structure (see section 3.5.2 and Table 3.18; and section 3.5.2.6 if allowing for thermal bridging)
4.x5	For internal walls, subtract the value in cell 2.1 in the worksheet for the adjoining room from the value in cell 2.1 in this worksheet (see 'Adjoining rooms' in section 3.5.3.3) For party walls, subtract 10 from value in cell 2.1 (see 'Adjoining properties and unheated spaces' in section 3.5.3.3) For 'other', follow the instructions for similar structures and conditions
4.x6	Multiply values from cells 4.x3, 4.x4 and 4.x5

Note: Internal walls are walls adjoining other rooms. Internal walls 1 and 2 may be used separately if two adjoining rooms have two different indoor design temperatures.

Note: 'Other' may be used for any other surface with a different construction or temperature difference, (e.g. internal doors, additional internal walls, and ceilings or floors spanning multiple adjoining rooms).

Floors

4.34, 4.35	Dimensions of the floor (see section 3.5.1.2)
4.36	Multiply the values in cells 4.34 and 4.35
4.37	U-value for appropriate floor type (see Tables 3.21 to 3.27, or section 3.5.2.4 for complex ground-floor structures; and section 3.5.2.6 if allowing for thermal bridging)
4.38	Temperature difference relative to the ground reference temperature (subtract value in cell 2.4 from value in cell 2.1) (see 'Ground temperature' in section 3.5.3.3)
4.39	Multiply values from cells 4.36, 4.37 and 4.38

Stage 5 – Design heat loss

5.1	Sum of all the values in column A
5.2	High-ceiling factor (see 'High ceiling' in section 3.5.3.2 and Figure 3.5)
5.3	If high ceilings are considered, multiply the values in cells 5.1 and 5.2 If high ceilings are not considered, the value is the value in cell 5.1

Intermittent heating (see section 3.5.5)

If intermittent heating not considered:

5.4–5.7	Not required, enter 0 for all cells
5.8	The value in cell 5.3

If intermittent heating is considered:

5.4–5.7, 5.x1–5.x2	See section 3.5.5
5.4	Period of disuse for room
5.5	Building air permeability
5.6	Building mass
5.x1	Selected reheat factors from Table 3.10
5.x2	Multiply the relative value in 5.x1 by the value in cell 4.36
5.7	Selected intermittent heating factor given the heat-up power in cells 5.x2
5.8	Multiply values in cells 5.3 and 5.7
5.9	Value in cell 5.8
5.10	Divide the value in cell 5.9 by the value in cell 4.36 (see the <i>Underfloor Heating Design & Installation Guide</i> ; also published by the Domestic Building Service Panel (https://www.dbsp.co.uk))

(CIBSE, 2021)

Appendix B.3 – a) Nursing Office Calculations

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

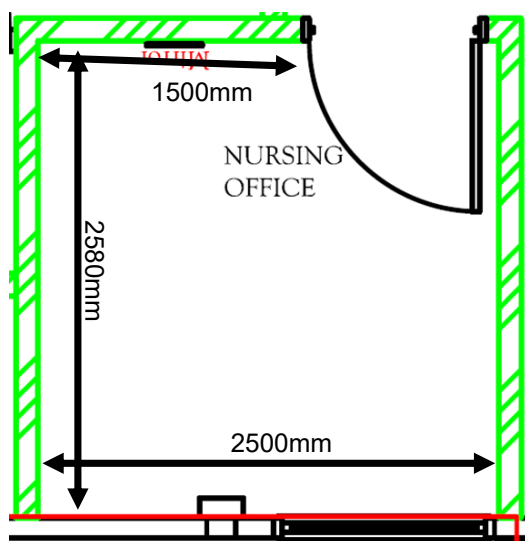
Room details:

Outside design temperature -3 °C
Ground reference temperature 6.5 °C
Room Design Temperature 21 °C
Design air changes per hour 6 ach

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m
High ceiling factor: 0 m



Heat Loss Calculation										
Stage 1 - Job Information										
Room	Nursing Office		Job	ASHP		Page	1	of	a)	
Stage 2 - Design Temperatures			Stage 3 - Ventilation Heat Loss							
Design Room Temperature	21		ach - No. of air changes per hour	Length (m)	Width (m)	Height (m)	m3/h - Amount of air heated per hour	Wm3K - Air change factor	oC - Design Temperature Difference	
Outside Design Temperature	-3									
Design Temperature Difference	24									
Ground Reference Temperature	6.5									
No. of ach for open flues and chimneys										
			6	2.58	2.5	2.36	91.332	0.33	24	723.349
			0				0	0	0	0
Stage 4 - Fabric Heat Loss			Thermal Bridging Addition							
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)			
External wall (gross area)(length outside x height)			2.58		2.36	6.0888				
Glazing				1.105	1.1	1.2155	2.3	24	67.0956	
External doors				0	0	0	3.7	24	0	
Net area of external wall (glazing and door areas subtracted)						4.8733	0.35	24	40.9357	
Ceiling or roof (gross areas)			2.58	2.5		6.45				
Roof glazing			0	0		0	0	0	0	
Net area of ceiling of roof (glazing area subtracted)						6.45	0.12	24	18.576	
External Wall 1			2.5		2.36	5.9	0.35	11	22.715	
Internal Wall 1			2.58		2.36	6.0888	1.92	0	0	
Internal Wall 2			1.5		2.36	3.54	1.92	0	0	
Internal Wall 3			2.58		2.36	6.0888	1.92	0	0	
Floor (gross area)			2.58	2.5		6.45	0.9	14.5	84.1725	
									233.495	
Stage 5 Design heat loss and estimated annual energy usage for room										
			956.844							
Reheat factor			Factor if YES							
Period of disues	Up to 11 hours		High ceiling?	0				956.844		
Building air permability	High		Intermittant heating?	1.2				1148.21		
Building mass	Low									
Reheat time:		Reheat facto	Heat-up power							
	0.5 hour	83	535.35							
	1 hour	47	303.15							
	2 hour	25	161.25							
	3 hour	14	90.3							
	4 hour	8	51.6							
	5 hour	3	19.35							
			TOTAL FOR ROOM						1148.21	
			Heat emission (W/m2)(total loss per unit floor area) including down loss						178.018	

Appendix B.4 – b) Data Cupboard Calculations

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

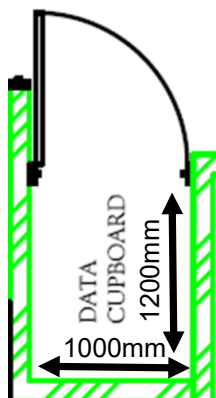
Outside design temperature -3 °C
Ground reference temperature 6.5 °C
Room Design Temperature 18 °C
Design air changes per hour 1 ach

Room details:

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	N/A
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	N/A
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m
High ceiling factor: 0 m



Heat Loss Calculation																
Stage 1 - Job Information																
Room	Data Cupboard		Job	ASHP		Page	1	of	b)							
Stage 2 - Design Temperatures			Stage 3 - Ventilation Heat Loss													
Design Room Temperature	18		ach - No. of air changes per hour	Length (m)	Width (m)	Height (m)	m3/h - Amount of air heated per hour	Wm3K - Air change factor	oC - Design Temperature Difference	Watts - Heat Loss						
Outside Design Temperature	-3															
Design Temperature Difference	21															
Ground Reference Temperature	6.5															
No. of ach for open flues and chimneys																
			1	1.2	1.4	2.36	3.9648	0.33	21	27.4761						
			0				0	0	0	0						
Stage 4 - Fabric Heat Loss			Thermal Bridging Addition													
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)									
External wall (gross area)(length outside x height)											0	0	0			
Glazing											0	0	0	2.3	21	0
External doors											0	0	0	3.7	21	0
Net area of external wall (glazing and door areas subtracted)													0	0.35	21	0
Ceiling or roof (gross areas)			1.2	1.4		1.68										
Roof glazing			0	0		0	0	0	0	0						
Net area of ceiling of roof (glazing area subtracted)						1.68	0.12	21	4.2336							
Internal Wall 1			1			2.36	2.36	1.92	0	0						
Internal Wall 2			1.2			2.36	2.832	1.92	0	0						
Internal Wall 3			1.2			2.36	2.832	1.92	0	0						
Floor (gross area)			1.2	1.4		1.68	0.9	11.5	17.388							
										21.6216						
Stage 5 Design heat loss and estimated annual energy usage for room										49.0977						
Reheat factor			Factor if YES													
Period of disues	Up to 11 hours		High ceiling?	0		49.0977										
Building air permability	High		Intermittant heating?	1.2		58.9172										
Building mass	Low															
Reheat time:			Reheat facto	Heat-up power												
	0.5 hour	83	139.44													
	1 hour	47	78.96													
	2 hour	25	42													
	3 hour	14	23.52		TOTAL FOR ROOM					58.9172						
	4 hour	8	13.44													
	5 hour	3	5.04													
Heat emission (W/m2)(total loss per unit floor area) including down loss										35.0698						

Appendix B.5 – c) Staff Room Calculations

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

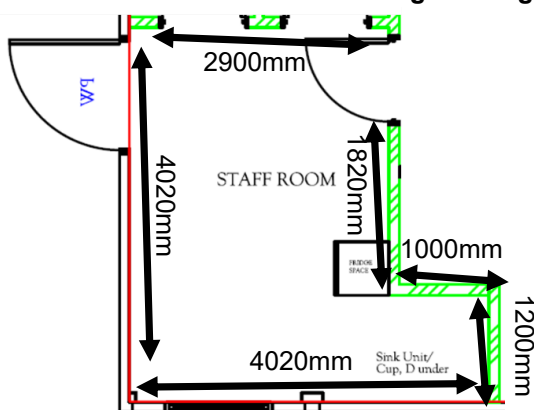
Outside design temperature -3 °C
 Ground reference temperature 6.5 °C
 Room Design Temperature 21 °C
 Design air changes per hour 6 ach

Room details:

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m
 High ceiling factor: 0 m



Heat Loss Calculation									
Stage 1 - Job Information									
Room	Staff Room	Job	ASHP	Page	1	of	c)		
Stage 2 - Design Temperatures				Stage 3 - Ventilation Heat Loss					
Design Room Temperature	21	ach - No. of air changes per hour	Length (m)	Width (m)	Height (m)	m3/h - Amount of air heated per hour	Wm3K - Air change factor	oC - Design Temperature Difference	Watts - Heat Loss
Outside Design Temperature	-3								
Design Temperature Difference	24								
Ground Reference Temperature	6.5								
No. of ach for open flues and chimneys									
		6	4.02	4.02	2.36	188.9	0.33	24	1496.09
		0				0	0	0	0
Stage 4 - Fabric Heat Loss				Thermal Bridging Addition					
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)		
External wall (gross area)(length outside x height)			8.04		2.36	18.9744			
Glazing				1.105	1.1	1.2155	2.3	24	67.0956
External doors				1.268	2.09	2.65012	3.7	24	235.331
Net area of external wall (glazing and door areas subtracted)						15.1088	0.35	24	126.914
Ceiling or roof (gross areas)			4.02	4.02		13.3404			
Roof glazing			0	0		0	0	0	0
Net area of ceiling of roof (glazing area subtracted)						13.3404	0.12	24	38.4204
External Wall 1			4.02		2.36	9.4872	0.35	11	36.5257
External Wall 2			4.02		2.36	9.4872	0.35	11	36.5257
Internal Wall 1			2.9		2.36	6.844	1.92	0	0
Internal Wall 2			1.82		2.36	4.2952	1.92	0	0
Internal Wall 3			1		2.36	2.36	1.92	0	0
Internal Wall 4			1.2		2.36	2.832	1.92	0	0
Floor (gross area)			4.02	2.9		11.658	0.9	14.5	152.137
			1.2	1		1.2	0.9	14.5	15.66
									167.797
									708.609
Stage 5 Design heat loss and estimated annual energy usage for room									2204.7
Period of disues	Reheat factor		Up to 11 hours		High ceiling?	Factor if YES		0	2204.7
Building air permability	High				Intermittant heating?	1.2		2645.64	
Building mass	Low								
Reheat time:	0.5 hour	83	1067.214						
	1 hour	47	604.326						
	2 hour	25	321.45						
	3 hour	14	180.012						
	4 hour	8	102.864						
	5 hour	3	38.574						
Heat emission (W/m2)(total loss per unit floor area) including down loss									205.758

Appendix B.6 – d) Male Change Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

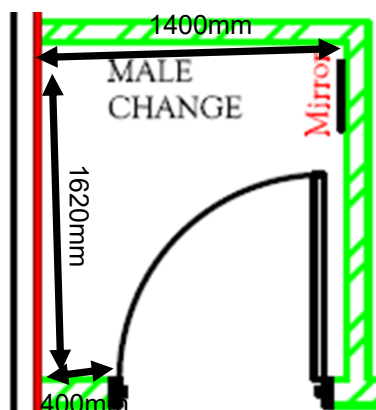
Room details:

Outside design temperature	-3	°C
Ground reference temperature	6.5	°C
Room Design Temperature	21	°C
Design air changes per hour	6	ach

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m
High ceiling factor: 0 m



Heat Loss Calculation									
Stage 1 - Job Information									
Room	Male Changing	Job	ASHP	Page	1	of	d)		
Stage 2 - Design Temperatures				Stage 3 - Ventilation Heat Loss					
Design Room Temperature	21	ach - No. of air changes per hour	Length (m)	Width (m)	Height (m)	m3/h - Amount of air heated per hour	Wm3K - Air change factor	oC - Design Temperature Difference	Watts - Heat Loss
Outside Design Temperature	-3								
Design Temperature Difference	24								
Ground Reference Temperature	6.5								
No. of ach for open flues and chimneys									
		6	1.62	1.4	2.36	32.1149	0.33	24	254.35
		0				0	0	0	0
Stage 4 - Fabric Heat Loss				Thermal Bridging Addition					
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)		
External wall (gross area)(length outside x height)			1.62		2.36	3.8232			
Glazing				0	0	0	2.3	24	0
External doors				0	0	0	3.7	24	0
Net area of external wall (glazing and door areas subtracted)						3.8232	0.35	24	32.1149
Ceiling or roof (gross areas)			1.62	1.4		2.268			
Roof glazing			0	0		0	0	0	0
Net area of ceiling of roof (glazing area subtracted)						2.268	0.12	24	6.53184
External Wall 1			1.62		2.36	3.8232	0.35	11	14.7193
Internal Wall 1			1.4		2.36	3.304	1.92	0	0
Internal Wall 2			0.4		2.36	0.944	1.92	0	0
Floor (gross area)			1.62	1.4		2.268	0.9	14.5	29.5974
									82.9634
Stage 5 Design heat loss and estimated annual energy usage for room									337.313
Reheat factor			Factor if YES						
Period of disues	Up to 11 hours	High ceiling?	0	337.313					
Building air permability	High	Intermittant heating?	1.2	404.776					
Building mass	Low								
Reheat time:			Reheat facto Heat-up power						
	0.5 hour	83	188.244						
	1 hour	47	106.596						
	2 hour	25	56.7						
	3 hour	14	31.752						
	4 hour	8	18.144						
	5 hour	3	6.804						
TOTAL FOR ROOM									404.776
Heat emission (W/m2)(total loss per unit floor area) including down loss									178.473

Appendix B.7 – e) Female Change Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

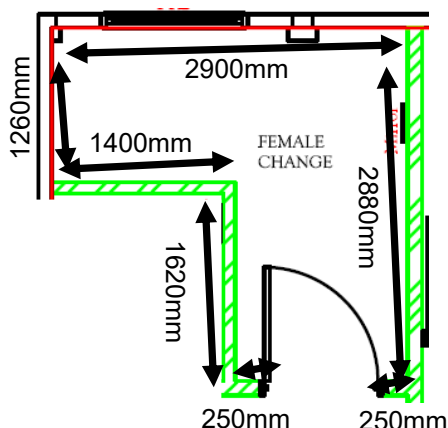
Room details:

Outside design temperature -3 °C
Ground reference temperature 6.5 °C
Room Design Temperature 21 °C
Design air changes per hour 10 ach

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m
High ceiling factor: 0 m



Heat Loss Calculation										
Stage 1 - Job Information										
Room	Female Changing		Job	ASHP		Page	1	of	e)	
Stage 2 - Design Temperatures			Stage 3 - Ventilation Heat Loss							
Design Room Temperature	21		ach - No. of air changes per hour	Length (m)	Width (m)	Height (m)	m ³ /h - Amount of air heated per hour	Wm ³ K - Air change factor	oC - Design Temperature Difference	
Outside Design Temperature	-3									
Design Temperature Difference	24									
Ground Reference Temperature	6.5									
No. of ach for open flues and chimneys										
			6	2.88	2.9	2.36	86.1494	0.33	24	682.304
			0				0	0	0	0
Stage 4 - Fabric Heat Loss			Thermal Bridging Addition							
			Length (m)	Width (m)	Height (m)	Area (m ²)	U Value (W/m ² K)			
External wall (gross area)(length outside x height)			1.62		2.36	3.8232				
Glazing				1.105	1.1	1.2155	2.3	24	67.0956	
External doors				0	0	0	3.7	24	0	
Net area of external wall (glazing and door areas subtracted)						2.6077	0.35	24	21.9047	
Ceiling or roof (gross areas)			2.88	2.9		6.084				
Roof glazing			0	0		0	0	0	0	
Net area of ceiling of roof (glazing area subtracted)						6.084	0.12	24	17.5219	
External Wall 1			1.26		2.36	2.9736	0.35	11	11.4484	
External Wall 2			1.26		2.36	2.9736	0.35	11	11.4484	
Internal Wall 1			1.4		2.36	3.304	1.92	0	0	
Internal Wall 3			2.8		2.36	6.608	1.92	0	0	
Internal Wall 4			0.25		2.36	0.59	1.92	0	0	
Internal Wall 5			0.25		2.36	0.59	1.92	0	0	
Floor (gross area)			1.26	2.9		3.654	0.9	14.5	47.6847	
			1.62	1.5		2.43	0.9	14.5	31.7115	
									79.3962	
									208.815	
Stage 5 Design heat loss and estimated annual energy usage for room			891.119							
Reheat factor			Factor if YES							
Period of disues	Up to 11 hours		High ceiling?				0	891.119		
Building air permability	High		Intermittant heating?				1.2	1069.34		
Building mass	Low									
Reheat time:			Reheat facto		Heat-up power					
	0.5 hour	83	504.972							
	1 hour	47	285.948							
	2 hour	25	152.1							
	3 hour	14	85.176							
	4 hour	8	48.672							
	5 hour	3	18.252							
TOTAL FOR ROOM							1069.34			
Heat emission (W/m ²)(total loss per unit floor area) including down loss							175.763			

Appendix B.8 – f) WC Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

Outside design temperature -3 °C

Ground reference temperature 6.5 °C

Room details:

Room Design Temperature 21 °C

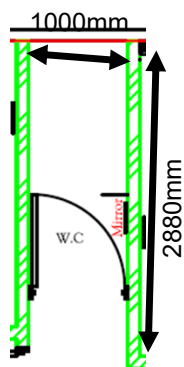
Design air changes per hour 6 ach

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.25
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m

High ceiling factor: 0 m



Heat Loss Calculation										
Stage 1 - Job Information										
Room	WC		Job	ASHP		Page	1	of	f)	
Stage 2 - Design Temperatures			Stage 3 - Ventilation Heat Loss							
Design Room Temperature	21		ach - No. of air changes per hour	Length (m)	Width (m)	Height (m)	m3/h - Amount of air heated per hour	Wm3K - Air change factor	oC - Design Temperature Difference	
Outside Design Temperature	-3									
Design Temperature Difference	24									
Ground Reference Temperature	6.5									
No. of ach for open flues and chimneys										
			6	2.88	1	2.36	40.7808	0.33	24	322.984
			0				0	0	0	0
Stage 4 - Fabric Heat Loss			Thermal Bridging Addition							
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)			
External wall (gross area)(length outside x height)			1			2.36	2.36			
Glazing				0	0	0	2.3	24	0	
External doors				0	0	0	3.7	24	0	
Net area of external wall (glazing and door areas subtracted)						2.36	0.35	24	19.824	
Ceiling or roof (gross areas)			2.88	1		0.612				
Roof glazing			0	0		0	0	0	0	
Net area of ceiling of roof (glazing area subtracted)						0.612	0.12	24	1.76256	
External Wall 1			1			2.36	2.36	0.35	11	9.086
Internal Wall 1			2.88			2.36	6.7968	1.92	0	0
Internal Wall 2			2.88			2.36	6.7968	1.92	0	0
Floor (gross area)			1	2.8		2.8	0.9	14.5	36.54	
									67.2126	
Stage 5 Design heat loss and estimated annual energy usage for room			390.196							
Reheat factor			Factor if YES							
Period of disuse	Up to 11 hours		High ceiling?	0		390.196				
Building air permeability	High		Intermittant heating?	1.2		468.236				
Building mass	Low									
Reheat time:			Reheat factor		Heat-up power					
	0.5 hour	83	232.4							
	1 hour	47	131.6							
	2 hour	25	70							
	3 hour	14	39.2		TOTAL FOR ROOM					
	4 hour	8	22.4		468.236					
	5 hour	3	8.4							
Heat emission (W/m2)(total loss per unit floor area) including down loss			167.227							

Appendix B.9 – g) Consulting Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

Outside design temperature -3 °C

Ground reference temperature 6.5 °C

Room Design Temperature 21 °C

Design air changes per hour 6 ach

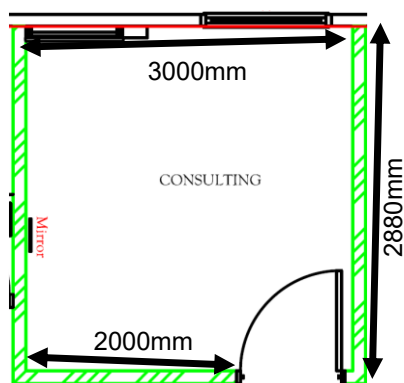
Room details:

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m

High ceiling factor: 0 m



Heat Loss Calculation									
Stage 1 - Job Information									
Room	Consulting	Job	ASHP	Page	1	of	g)		
Stage 2 - Design Temperatures			Stage 3 - Ventilation Heat Loss						
Design Room Temperature	21	ach - No. of air changes per hour	Length (m)	Width (m)	Height (m)	m3/h - Amount of air heated per hour	Wm3K - Air change factor	oC - Design Temperature Difference	Watts - Heat Loss
Outside Design Temperature	-3								
Design Temperature Difference	24								
Ground Reference Temperature	6.5								
No. of ach for open flues and chimneys									
		6	2.88	3	2.36	122.342	0.33	24	968.952
		0				0	0	0	0
Stage 4 - Fabric Heat Loss			Thermal Bridging Addition						
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)		
External wall (gross area)(length outside x height)			3		2.36	7.08			
Glazing				1.105	1.1	1.2155	2.3	24	67.0956
External doors				0	0	0	3.7	24	0
Net area of external wall (glazing and door areas subtracted)						5.8645	0.35	24	49.2618
Ceiling or roof (gross areas)			2.88	3		6.372			
Roof glazing			0	0		0	0	0	0
Net area of ceiling of roof (glazing area subtracted)						6.372	0.12	24	18.3514
External Wall 1			3		2.36	7.08	0.35	11	27.258
Internal Wall 1			2.88		2.36	6.7968	1.92	0	0
Internal Wall 2			2.88		2.36	6.7968	1.92	0	0
Internal Wall 3			2		2.36	4.72	1.92	0	0
Floor (gross area)			2.88	3		8.64	0.9	14.5	112.752
									274.719
Stage 5 Design heat loss and estimated annual energy usage for room									1243.67
Period of disues	Reheat factor		Up to 11 hours		High ceiling?	Factor if YES		0	1243.67
Building air permability			High		Intermittant heating?	1.2		1492.4	
Building mass			Low						
Reheat time:	0.5 hour	Reheat facto	83	Heat-up power					
	1 hour		47	406.08					
	2 hour		25	216					
	3 hour		14	120.96					
	4 hour		8	69.12					
	5 hour		3	25.92					
TOTAL FOR ROOM									1492.4
Heat emission (W/m2)(total loss per unit floor area) including down loss									172.732

Appendix B.10 – h) WC Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

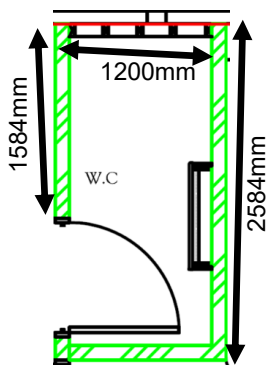
Outside design temperature -3 °C
Ground reference temperature 6.5 °C
Room Design Temperature 21 °C
Design air changes per hour 6 ach

Room details:

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m
High ceiling factor: 0 m



Heat Loss Calculation										
Stage 1 - Job Information										
Room	WC		Job	ASHP		Page	1		of h)	
Stage 2 - Design Temperatures			Stage 3 - Ventilation Heat Loss							
Design Room Temperature	21		ach - No. of air changes per hour	Length (m)	Width (m)	Height (m)	m3/h - Amount of air heated per hour	Wm3K - Air change factor	oC - Design Temperature Difference	
Outside Design Temperature	-3									
Design Temperature Difference	24									
Ground Reference Temperature	6.5									
No. of ach for open flues and chimneys										
			6	2.584	1.2	2.36	43.9073	0.33	24	347.746
			0				0	0	0	0
Stage 4 - Fabric Heat Loss			Thermal Bridging Addition							
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)			
External wall (gross area)(length outside x height)			1.2		2.36	2.832				
Glazing				0	0	0	2.3	24	0	
External doors				0	0	0	3.7	24	0	
Net area of external wall (glazing and door areas subtracted)						2.832	0.35	24	23.7888	
Ceiling or roof (gross areas)			2.584	1.2		0.8328				
Roof glazing			0	0		0	0	0	0	
Net area of ceiling of roof (glazing area subtracted)						0.8328	0.12	24	2.39846	
External Wall 1			1.2		2.36	2.832	0.35	11	10.9032	
Internal Wall 1			2.584		2.36	6.09824	1.92	0	0	
Internal Wall 2			1.584		2.36	3.73824	1.92	0	0	
Internal Wall 3			1.2		2.36	2.832	1.92	0	0	
Floor (gross area)			2.584	1.2		3.1008	0.9	14.5	40.4654	
									77.5559	
Stage 5 Design heat loss and estimated annual energy usage for room									425.302	
Reheat factor			Factor if YES							
Period of disues	Up to 11 hours		High ceiling?	0		425.302				
Building air permability	High		Intermittant heating?	1.2		510.362				
Building mass	Low									
Reheat time:	Reheat facto		Heat-up power							
	0.5 hour	83	257.3664							
	1 hour	47	145.7376							
	2 hour	25	77.52							
	3 hour	14	43.4112							
	4 hour	8	24.8064							
	5 hour	3	9.3024							
			TOTAL FOR ROOM						510.362	
			Heat emission (W/m2)(total loss per unit floor area) including down loss						164.591	

Appendix B.11 – i) Treatment Area Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

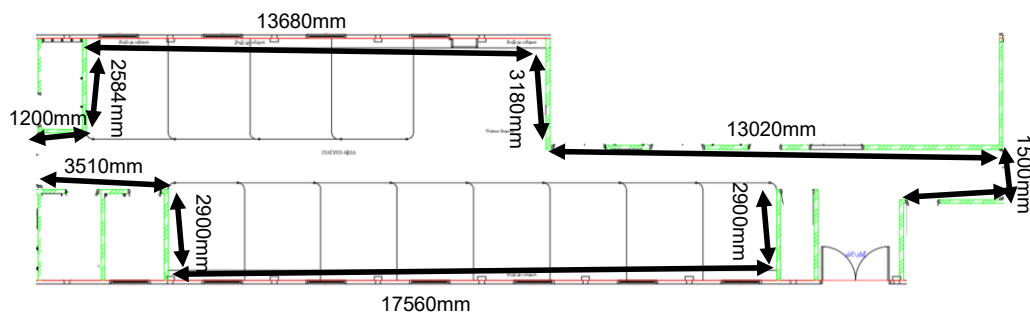
Room details:

Outside design temperature -3 °C
Ground reference temperature 6.5 °C
Room Design Temperature 21 °C
Design air changes per hour 6 ach

Building Element	Construction	U Value W/m²k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m
High ceiling factor: 0 m



Heat Loss Calculation											
Stage 1 - Job Information											
Room	Treatment Area	Job	ASHP		Page	1	of	i)			
Stage 2 - Design Temperatures					Stage 3 - Ventilation Heat Loss						
Design Room Temperature	21		ach - No. of air changes per hour	Length (m)	Width (m)	Room Volume	Height (m)	m ³ /h - Amount of air heated per hour	Wm ³ K - Air change factor	oC - Design Temperature Difference	Watts - Heat Loss
Outside Design Temperature	-3										
Design Temperature Difference	24										
Ground Reference Temperature	6.5										
No. of ach for open flues and chimneys											
			6	7.58	26.7	2.36	1976.91	0.33	24	15657.1	
			0				0	0	0	0	
Stage 4 - Fabric Heat Loss					Thermal Bridging Addition						
			Length (m)	Width (m)	Height (m)	Area (m ²)	U Value (W/m ² K)				
External wall (gross area)(length outside x height)			33.331		2.36	78.6612					
Glazing				11.05	1.1	12.155	2.3	24	670.956		
External doors				2.091	2.09	4.37019	3.7	24	388.073		
Net area of external wall (glazing and door areas subtracted)						62.136	0.35	24	521.942		
Ceiling or roof (gross areas)			7.58	26.7		200.118					
Roof glazing			0	0		0	0	0	0		
Net area of ceiling of roof (glazing area subtracted)						200.118	0.12	24	576.34		
External Wall 1			13.68		2.36	32.2848	0.35	11	124.296		
External Wall 2			17.56		2.36	41.4416	0.35	11	159.55		
Internal Wall 1			3.18		2.36	7.5048	1.92	0	0		
Internal Wall 2			13.02		2.36	30.7272	1.92	0	0		
Internal Wall 4			2.97		2.36	7.0092	1.92	0	0		
Internal Wall 5			2.28		2.36	5.3808	1.92	0	0		
Internal Wall 6			2.9		2.36	6.844	1.92	0	0		
Internal Wall 7			2.9		2.36	6.844	1.92	0	0		
Internal Wall 8			2.9		2.36	6.844	1.92	0	0		
Internal Wall 9			0.755		2.36	1.7818	1.92	0	0		
Internal Wall 10			0.755		2.36	1.7818	1.92	0	0		
Floor (gross area)			13.68	3.18		43.5024	0.9	14.5	567.706		
			2.97	1.5		4.455	0.9	14.5	58.1378		
			2.901	3.78		10.9658	0.9	14.5	143.103		
			17.56	2.9		50.924	0.9	14.5	664.558		
			22.59	1.5		33.885	0.9	14.5	442.199		
									1875.7		
									4316.86		
Stage 5 Design heat loss and estimated annual energy usage for room											
19974											
Reheat factor			Factor if YES								
Period of disuse	Up to 11 hours		High ceiling?	0		19974					
Building air permeability	High		Intermittant heating?	1.2		23968.8					
Building mass	Low										
Reheat time:	0.5 hour	Reheat factor	Heat-up power								
	1 hour	83	11929.77094								
	2 hour	47	6755.41246								
	3 hour	25	3593.3045								
	4 hour	14	2012.25052								
	5 hour	8	1149.85744								
		3	431.19654								
TOTAL FOR ROOM						23968.8					
Heat emission (W/m ²)(total loss per unit floor area) including down loss											
166.76											

Appendix B.12 – j) Isolation Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

Outside design temperature -3 °C

Ground reference temperature 6.5 °C

Room details:

Room Design Temperature 21 °C

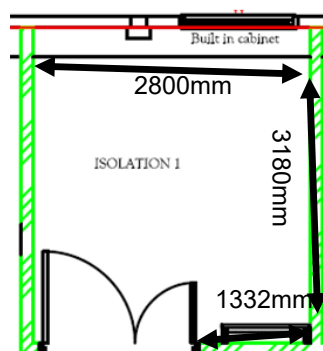
Design air changes per hour 10 ach

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m

High ceiling factor: 0 m



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Appendix B.13 – k) Line Insertion Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

Outside design temperature -3 °C

Ground reference temperature 6.5 °C

Room details:

Room Design Temperature 21 °C

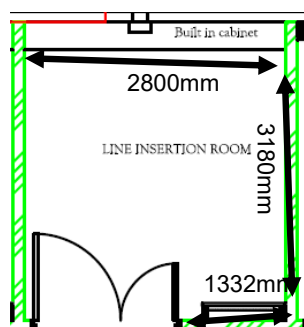
Design air changes per hour 6 ach

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m

High ceiling factor: 0 m



Heat Loss Calculation										
Stage 1 - Job Information										
Room	Line Inserion Room		Job	ASHP		Page	1	of	k)	
Stage 2 - Design Temperatures			Stage 3 - Ventilation Heat Loss							
Design Room Temperature	21		ach - No. of air changes per hour	Length (m)	Width (m)	Height (m)	m3/h - Amount of air heated per hour	Wm3K - Air change factor	oC - Design Temperature Difference	
Outside Design Temperature	-3									
Design Temperature Difference	24									
Ground Reference Temperature	6.5									
No. of ach for open flues and chimneys										
			6	3.18	2.8	2.36	126.081	0.33	24	998.559
			0				0	0	0	0
Stage 4 - Fabric Heat Loss			Thermal Bridging Addition							
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)			
External wall (gross area)(length outside x height)										
Glazing										
External doors										
Net area of external wall (glazing and door areas subtracted)										
			2.8		2.36	6.608				
				1.105	1.1	1.2155	2.3	24	67.0956	
				0	0	0	3.7	24	0	
						5.3925	0.35	24	45.297	
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)			
Ceiling or roof (gross areas)										
Roof glazing										
Net area of ceiling of roof (glazing area subtracted)										
			3.18	2.8		6.636				
			0	0		0	0	0	0	
						6.636	0.12	24	19.1117	
			External Wall 1	2.8		2.36	6.608	0.35	11	25.4408
			Internal Wall 1	3.18		2.36	7.5048	1.92	0	0
			Internal Wall 2	1.332		2.36	3.14352	1.92	0	0
			Internal Wall 3	3.18		2.36	7.5048	1.92	0	0
			Floor (gross area)	3.18	2.8		8.904	0.9	14.5	116.197
										116.197
										273.142
Stage 5 Design heat loss and estimated annual energy usage for room										
										1271.7
			Reheat factor			Factor if YES				
Period of disues	Up to 11 hours					0				1271.7
Building air permability	High					1.2				1526.04
Building mass	Low									
			Reheat facto	Heat-up power						
Reheat time:	0.5 hour	83	739.032							
	1 hour	47	418.488							
	2 hour	25	222.6							
	3 hour	14	124.656							
	4 hour	8	71.232							
	5 hour	3	26.712							
TOTAL FOR ROOM										1526.04
Heat emission (W/m2)(total loss per unit floor area) including down loss										171.388

Appendix B.14 – I) Dirty Utility Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

Outside design temperature -3 °C

Ground reference temperature 6.5 °C

Room details:

Room Design Temperature 21 °C

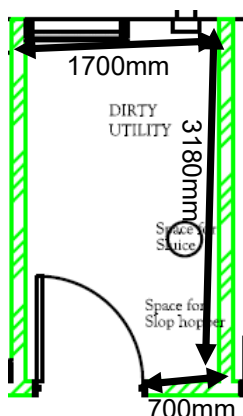
Design air changes per hour 6 ach

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m

High ceiling factor: 0 m



Heat Loss Calculation																
Stage 1 - Job Information																
Room	Dirty Utility		Job	ASHP		Page	1	of 1)								
Stage 2 - Design Temperatures			Stage 3 - Ventilation Heat Loss													
			ach - No. of air changes per hour	Length (m)	Width (m)	Height (m)	m3/h - Amount of air heated per hour	Wm3K - Air change factor	oC - Design Temperature Difference	Watts - Heat Loss						
Design Room Temperature		21														
Outside Design Temperature		-3														
Design Temperature Difference		24														
Ground Reference Temperature		6.5														
No. of ach for open flues and chimneys			6	3.18	1.7	2.36	76.549	0.33	24	606.268						
			0				0	0	0	0						
Stage 4 - Fabric Heat Loss			Thermal Bridging Addition													
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)									
External wall (gross area)(length outside x height)		0									0	0				
Glazing											0	0	0	2.3	24	0
External doors											0	0	0	3.7	24	0
Net area of external wall (glazing and door areas subtracted)													0	0.35	24	0
Ceiling or roof (gross areas)			3.18	1.7		3.138										
Roof glazing			0	0		0	0	0	0							
Net area of ceiling of roof (glazing area subtracted)						3.138	0.12	24	9.03744							
Internal Wall 1			1.7		2.36	4.012	0.35	0	0							
Internal Wall 2			3.18		2.36	7.5048	1.92	0	0							
Internal Wall 3			0.7		2.36	1.652	1.92	0	0							
Internal Wall 4			3.18		2.36	7.5048	1.92	0	0							
Floor (gross area)			3.18	1.7		5.406	0.9	14.5	70.5483	70.5483						
										79.5857						
Stage 5 Design heat loss and estimated annual energy usage for room										685.854						

Appendix B.15 – m) Water Treatment Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

Outside design temperature -3 °C

Ground reference temperature 6.5 °C

Room details:

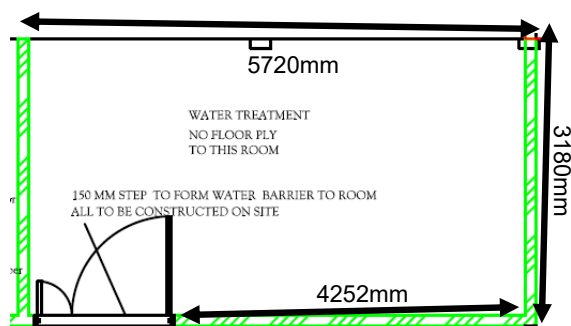
Room Design Temperature 21 °C

Design air changes per hour 4 ach

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m
High ceiling factor: 0 m



Heat Loss Calculation										
Stage 1 - Job Information										
Room	Water Treatment		Job	ASHP		Page	1	of	(m)	
Stage 2 - Design Temperatures			Stage 3 - Ventilation Heat Loss							
Design Room Temperature	21		ach - No. of air changes per hour	Length (m)	Width (m)	Height (m)	m ³ /h - Amount of air heated per hour	Wm ³ K - Air change factor	oC - Design Temperature Difference	
Outside Design Temperature	-3									
Design Temperature Difference	24									
Ground Reference Temperature	6.5									
No. of ach for open flues and chimneys										
			4	3.18	5.72	2.36	171.71	0.33	24	1359.94
			0				0	0	0	0
Stage 4 - Fabric Heat Loss			Thermal Bridging Addition							
				Length (m)	Width (m)	Height (m)	Area (m ²)	U Value (W/m ² K)		
External wall (gross area)(length outside x height)				0		0	0			
Glazing					0	0	0	2.3	24	0
External doors					0	0	0	3.7	24	0
Net area of external wall (glazing and door areas subtracted)							0	0.35	24	0
Ceiling or roof (gross areas)				3.18	5.72		15.9216			
Roof glazing				0	0		0	0	0	0
Net area of ceiling of roof (glazing area subtracted)							15.9216	0.12	24	45.8542
Internal Wall 1				4.252		2.36	10.0347	0.35	0	0
Internal Wall 2				3.18		2.36	7.5048	1.92	0	0
Internal Wall 3				5.72		2.36	13.4992	1.92	0	0
Internal Wall 4				3.18		2.36	7.5048	1.92	0	0
Floor (gross area)				3.18	5.72		18.1896	0.9	14.5	237.374
										237.374
										283.228
Stage 5 Design heat loss and estimated annual energy usage for room										1643.17
Reheat factor			Factor if YES							
Period of disues	Up to 11 hours		High ceiling?	0		1643.17				
Building air permability	High		Intermittant heating?	1.2		1971.8				
Building mass	Low									
Reheat time:			Reheat facto	Heat-up power						
	0.5 hour	83	1509.7368							
	1 hour	47	854.9112							
	2 hour	25	454.74							
	3 hour	14	254.6544	TOTAL FOR ROOM						
	4 hour	8	145.5168	1971.8						
	5 hour	3	54.5688							
Heat emission (W/m ²)(total loss per unit floor area) including down loss			108.403							

Appendix B.16 – n) Store Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

Outside design temperature -3 °C

Ground reference temperature 6.5 °C

Room details:

Room Design Temperature 21 °C

Design air changes per hour 6 ach

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m

High ceiling factor: 0 m



Heat Loss Calculation										
Stage 1 - Job Information										
Room	Store	Job	ASHP		Page	1	of	n)		
Stage 2 - Design Temperatures			Stage 3 - Ventilation Heat Loss							
Design Room Temperature	21		ach - No. of air changes per hour	Length (m)	Width (m)	Height (m)	m3/h - Amount of air heated per hour	Wm3K - Air change factor	oC - Design Temperature Difference	Watts - Heat Loss
Outside Design Temperature	-3									
Design Temperature Difference	24									
Ground Reference Temperature	6.5									
No. of ach for open flues and chimneys										
			6	4.8	2.97	2.36	201.865	0.33	24	1598.77
			0				0	0	0	0
Stage 4 - Fabric Heat Loss			Thermal Bridging Addition							
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)			
External wall (gross area)(length outside x height)			7.77		2.36	18.3372				
Glazing				0	0	0	2.3	24	0	
External doors				0	0	0	3.7	24	0	
Net area of external wall (glazing and door areas subtracted)						18.3372	0.35	24	154.032	
Ceiling or roof (gross areas)			4.8	2.97		11.988				
Roof glazing			0	0		0	0	0	0	
Net area of ceiling of roof (glazing area subtracted)						11.988	0.12	24	34.5254	
External Wall 1			2.97		2.36	7.0092	0.35	11	26.9854	
External Wall 2			4.8		2.36	11.328	1.92	11	239.247	
Internal Wall 1			2.97		2.36	7.0092	1.92	0	0	
Internal Wall 4			3.18		2.36	7.5048	1.92	0	0	
Floor (gross area)			4.8	2.97		14.256	0.9	14.5	186.041	
									186.041	
									640.832	
Stage 5 Design heat loss and estimated annual energy usage for room										
			2239.6							
Reheat factor			Factor if YES							
Period of disues	Up to 11 hours		High ceiling?		0		2239.6			
Building air permability	High		Intermittant heating?		1.2		2687.52			
Building mass	Low									
Reheat time:			Reheat facto		Heat-up power					
	0.5 hour	83	1183.248							
	1 hour	47	670.032							
	2 hour	25	356.4							
	3 hour	14	199.584							
	4 hour	8	114.048							
	5 hour	3	42.768							
			TOTAL FOR ROOM						2687.52	
			Heat emission (W/m2)(total loss per unit floor area) including down loss						188.519	

Appendix B.17 – o) Workshop Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

Outside design temperature -3 °C

Ground reference temperature 6.5 °C

Room details:

Room Design Temperature 21 °C

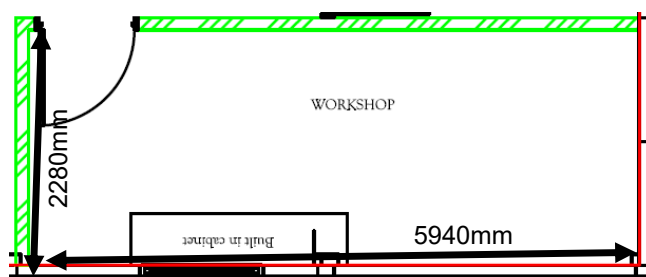
Design air changes per hour 6 ach

Building Element	Construction	U Value W/m²k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m

High ceiling factor: 0 m



Heat Loss Calculation										
Stage 1 - Job Information										
Room	Workshop		Job	ASHP		Page	1	of	o)	
Stage 2 - Design Temperatures			Stage 3 - Ventilation Heat Loss							
Design Room Temperature	21		ach - No. of air changes per hour	Length (m)	Width (m)	Height (m)	m3/h - Amount of air heated per hour	Wm3K - Air change factor	oC - Design Temperature Difference	
Outside Design Temperature	-3									
Design Temperature Difference	24									
Ground Reference Temperature	6.5									
No. of ach for open flues and chimneys										
			6	5.94	2.28	2.36	191.772	0.33	24	1518.83
			0				0	0	0	0
Stage 4 - Fabric Heat Loss			Thermal Bridging Addition							
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)			
External wall (gross area)(length outside x height)										
Glazing										
External doors										
Net area of external wall (glazing and door areas subtracted)										
			8.22		2.36	19.3992				
				1.105	1.1	1.2155	2.3	24	67.0956	
				0	0	0	3.7	24	0	
						18.1837	0.35	24	152.743	
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)			
Ceiling or roof (gross areas)										
Roof glazing										
Net area of ceiling of roof (glazing area subtracted)										
			5.94	2.28		11.2752				
			0	0		0	0	0	0	
						11.2752	0.12	24	32.4726	
			External Wall 1	2.28		2.36	5.3808	0.35	11	20.7161
			External Wall 2	5.94		2.36	14.0184	1.92	11	296.069
			Internal Wall 1	2.28		2.36	5.3808	1.92	0	0
			Internal Wall 4	5.94		2.36	14.0184	1.92	0	0
			Floor (gross area)	5.94	2.28		13.5432	0.9	14.5	176.739
										176.739
										745.835
Stage 5 Design heat loss and estimated annual energy usage for room										
			Reheat factor		Factor if YES					
Period of disues	Up to 11 hours		High ceiling?		0		2264.67			
Building air permability	High		Intermittant heating?		1.2		2717.6			
Building mass	Low									
			Reheat facto		Heat-up power					
Reheat time:	0.5 hour	83	1124.0856							
	1 hour	47	636.5304							
	2 hour	25	338.58							
	3 hour	14	189.6048							
	4 hour	8	108.3456							
	5 hour	3	40.6296							
			TOTAL FOR ROOM						2717.6	
			Heat emission (W/m2)(total loss per unit floor area) including down loss						200.662	

Appendix B.18 – p) Cleaner Store Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

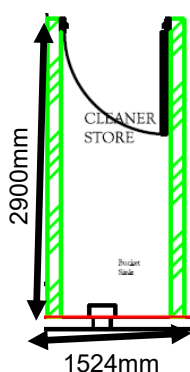
Outside design temperature -3 °C
Ground reference temperature 6.5 °C
Room Design Temperature 21 °C
Design air changes per hour 6 ach

Room details:

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m
High ceiling factor: 0 m



Heat Loss Calculation									
Stage 1 - Job Information									
Room	Cleaners Store	Job	ASHP	Page	1	of	p)		
Stage 2 - Design Temperatures			Stage 3 - Ventilation Heat Loss						
Design Room Temperature	21	ach - No. of air changes per hour	Length (m)	Width (m)	Height (m)	m3/h - Amount of air heated per hour	Wm3K - Air change factor	oC - Design Temperature Difference	Watts - Heat Loss
Outside Design Temperature	-3								
Design Temperature Difference	24								
Ground Reference Temperature	6.5								
No. of ach for open flues and chimneys									
		6	2.9	1.524	2.36	62.5815	0.33	24	495.646
		0				0	0	0	0
Stage 4 - Fabric Heat Loss			Thermal Bridging Addition						
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)		
External wall (gross area)(length outside x height)			1		2.36	2.36			
Glazing				0	0	0	2.3	24	0
External doors				0	0	0	3.7	24	0
Net area of external wall (glazing and door areas subtracted)						2.36	0.35	24	19.824
Ceiling or roof (gross areas)			2.9	1.524		2.1516			
Roof glazing			0	0		0	0	0	0
Net area of ceiling of roof (glazing area subtracted)						2.1516	0.12	24	6.19661
External Wall 1			1.524		2.36	3.59664	0.35	11	13.8471
Internal Wall 1			2.9		2.36	6.844	1.92	0	0
Internal Wall 2			2.9		2.36	6.844	1.92	0	0
Floor (gross area)			2.9	1.524		4.4196	0.9	14.5	57.6758
									57.6758
									97.5435
Stage 5 Design heat loss and estimated annual energy usage for room									593.189
Period of disues	Up to 11 hours	Reheat factor	Factor if YES						
Building air permability	High		High ceiling?	0				593.189	
Building mass	Low		Intermittant heating?	1.2				711.827	
Reheat time:	0.5 hour	Reheat facto	Heat-up power						
	1 hour	83	366.8268						
	2 hour	47	207.7212						
	3 hour	25	110.49						
	4 hour	14	61.8744						
	5 hour	8	35.3568						
		3	13.2588						
TOTAL FOR ROOM								711.827	
Heat emission (W/m2)(total loss per unit floor area) including down loss								161.061	

Appendix B.19 – q) Clean Utility Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

Outside design temperature -3 °C

Ground reference temperature 6.5 °C

Room details:

Room Design Temperature 21 °C

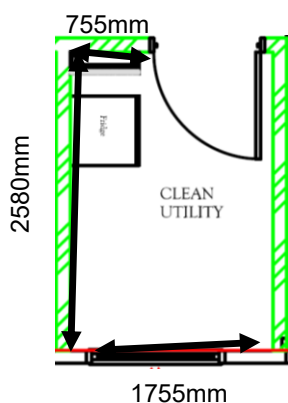
Design air changes per hour 6 ach

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m

High ceiling factor: 0 m



[illegible]

Stage 1 - Job Information									
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Room	Clean Utility	Job	ASHP	Page	1	of	q)
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Stage 2 - Design Temperatures					
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Stage 3 - Ventilation Heat Loss					

Design Room Temperature	21
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Outside Design Temperature	-3
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Design Temperature Difference	24
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Ground Reference Temperature	6.5
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No. of ach for open flues and chimneys					
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each - No. of air changes per hour	6						
Length (m)	2.58						
Width (m)	1.755						
Height (m)	2.36						
m3/h - Amount of air heated per hour	64.1151						
Wm3K - Air change factor	0.33						
oC - Design Temperature Difference	24						
Watts - Heat Loss	507.791						

Stage 4 - Fabric Heat Loss					

Thermal Bridging Addition	
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External wall (gross area)(length outside x height)	
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Glazing		1.105	1.1	1.2155	2.3	24	67.0956
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External doors	0	0	0	3.7	24	0
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Net area of external wall (glazing and door areas subtracted)						2.9263	0.35	24	24.5809
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Ceiling or roof (gross areas)	2.58	1.755	2.2599			
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Roof glazing	0	0	0	0	0	0
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Net area of ceiling of roof (glazing area subtracted)	2.2599	0.12	24	6.50851
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External Wall 1	1.755	2.36	4.1418	0.35	11	15.9459
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Internal Wall 1	2.58	2.36	6.0888	1.92	0	0
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Internal Wall 2	2.58	2.36	6.0888	1.92	0	0
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Internal Wall 3	0.755	2.36	1.7818	1.92	0	0
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Floor (gross area)	2.58	1.755	4.5279	0.9	14.5	59.0891
						59.0891

173.22

Stage 5 Design heat loss and estimated annual energy usage for room										681.011
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		Reheat factor
Period of disuses	Up to 11 hours	
Building air permeability	High	
Building mass	Low	

		Factor if YES		
High ceiling?		0		681.011
Intermittant heating?		1.2		817.214

		Reheat facto	Heat-up power
Reheat time:	0.5 hour	83	375.8157
	1 hour	47	212.8113
	2 hour	25	113.1975
	3 hour	14	63.3906
	4 hour	8	36.2232
	5 hour	3	13.5837

TOTAL FOR ROOM	817.214
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Heat emission (W/m2)(total loss per unit floor area) including down loss	180.484
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Appendix B.20 – r) Kitchen Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

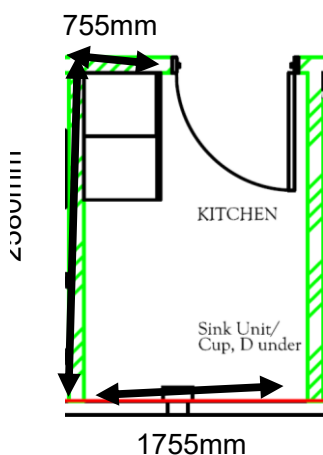
Room details:

Outside design temperature -3 °C
 Ground reference temperature 6.5 °C
 Room Design Temperature 21 °C
 Design air changes per hour 6 ach

Building Element	Construction	U Value W/m²k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m
 High ceiling factor: 0 m



[illegible]

Stage 1 - Job Information									
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Room	Kitchen	Job	ASHP	Page	1	of	r)
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Stage 2 - Design Temperatures					
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Stage 3 - Ventilation Heat Loss

Design Room Temperature	21
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Outside Design Temperature	-3	air cl	Rc	unt of	chang	Temp	t Loss
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Design Temperature Difference	24
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Ground Reference Temperature	6.5
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No. of ach for open flues and chimneys	0				0	0	0	0
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Stage 4 - Fabric Heat Loss				
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Thermal Bridging Addition		
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					Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)		

External wall (gross area)/(length outside x height)	1.755	2.36	4.1418
--	-------	------	--------

Glazing	0	0	0	2.3	24	0
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External doors	0	0	0	3.7	24	0
(as subtracted)			4 1418	0 35	24	34 7911

Net area of external wall (glazing and door areas subtracted)		4.1418	0.35	24	34.7911
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Ceiling or roof (gross areas)	2.58	1.755	2.2599			
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Roof glazing	0	0	0	0	0	0
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Net area of ceiling of roof (glazing area subtracted)	2.2599	0.12	24	6.50851
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External Wall 1	1.755	2.36	4.1418	0.35	11	15.9459
-----------------	-------	------	--------	------	----	---------

Internal Wall 1	2.58	2.36	6.0888	1.92	0	0
-----------------	------	------	--------	------	---	---

Internal Wall 2	2.58	2.36	6.0888	1.92	0	0
-----------------	------	------	--------	------	---	---

Internal Wall 3	0.755	2.36	1.7818	1.92	0	0
-----------------	-------	------	--------	------	---	---

Floor (gross area)	2.58	1.755	4.5279	0.9	14.5	59.0891
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59.0891

116.335

Stage 5 Design heat loss and estimated annual energy usage for room										624.126
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		Reheat factor
Period of disuses	Up to 11 hours	
Building air permeability	High	
Building mass	Low	

		Factor if YES		
High ceiling?		0		624.126
Intermittant heating?		1.2		748.951

		Reheat facto	Heat-up power
Reheat time:	0.5 hour	83	375.8157
	1 hour	47	212.8113
	2 hour	25	113.1975
	3 hour	14	63.3906
	4 hour	8	36.2232
	5 hour	3	13.5837

TOTAL FOR ROOM	748.951
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Heat emission (W/m ²)(total loss per unit floor area) including down loss	165.408
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Appendix B.21 – s) Disabled WC Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

Outside design temperature -3 °C

Ground reference temperature 6.5 °C

Room details:

Room Design Temperature 21 °C

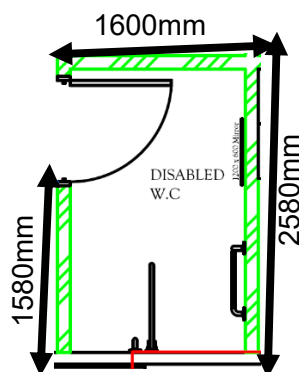
Design air changes per hour 6 ach

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m

High ceiling factor: 0 m



Heat Loss Calculation										
Stage 1 - Job Information										
Room	Disabled WC		Job	ASHP		Page	1	of	s)	
Stage 2 - Design Temperatures			Stage 3 - Ventilation Heat Loss							
Design Room Temperature	21		ach - No. of air changes per hour	Length (m)	Width (m)	Height (m)	m3/h - Amount of air heated per hour	Wm3K - Air change factor	oC - Design Temperature Difference	
Outside Design Temperature	-3									
Design Temperature Difference	24									
Ground Reference Temperature	6.5									
No. of ach for open flues and chimneys										
			6	2.58	1.6	2.36	58.4525	0.33	24	462.944
			0				0	0	0	0
Stage 4 - Fabric Heat Loss			Thermal Bridging Addition							
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)			
External wall (gross area)(length outside x height)										
Glazing										
External doors										
Net area of external wall (glazing and door areas subtracted)										
			0.84		2.36	1.9824				
				0	0	0	2.3	24	0	
				0	0	0	3.7	24	0	
						1.9824	0.35	24	16.6522	
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)			
Ceiling or roof (gross areas)										
Roof glazing										
Net area of ceiling of roof (glazing area subtracted)										
			2.58	1.6		1.86				
			0	0		0	0	0	0	
						1.86	0.12	24	5.3568	
			External Wall 1	0.84		2.36	1.9824	0.35	11	7.63224
			Internal Wall 1	2.58		2.36	6.0888	1.92	0	0
			Internal Wall 2	1.6		2.36	3.776	1.92	0	0
			Internal Wall 3	1.58		2.36	3.7288	1.92	0	0
			Floor (gross area)	2.58	1.6		4.128	0.9	14.5	53.8704
										53.8704
										83.5116
Stage 5 Design heat loss and estimated annual energy usage for room										
			Reheat factor		Factor if YES					
Period of disues	Up to 11 hours		High ceiling?		0		546.455			
Building air permability	High		Intermittant heating?		1.2		655.746			
Building mass	Low									
			Reheat facto	Heat-up power						
Reheat time:	0.5 hour	83	342.624							
	1 hour	47	194.016							
	2 hour	25	103.2							
	3 hour	14	57.792							
	4 hour	8	33.024							
	5 hour	3	12.384							
			TOTAL FOR ROOM						655.746	
			Heat emission (W/m2)(total loss per unit floor area) including down loss						158.853	

Appendix B.22 – t) Waiting Area Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

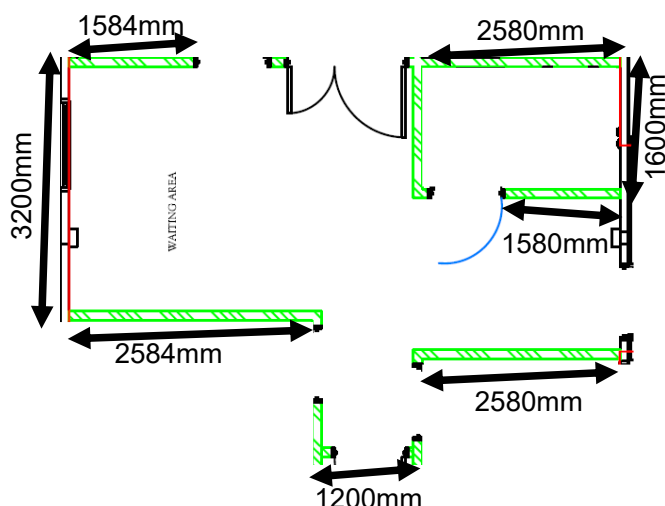
Room details:

Outside design temperature -3 °C
 Ground reference temperature 6.5 °C
 Room Design Temperature 21 °C
 Design air changes per hour 6 ach

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m
 High ceiling factor: 0 m



[illegible]

Stage 1 - Job Information												
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Room	Waiting Area	Job	ASHP	Page	1	of	t)
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Stage 2 - Design Temperatures				Stage 3 - Ventilation Heat Loss			
Room	Room Temp	Design Temp	Room	Room Temp	Design Temp	Room	Room Temp
Room 1	18	15	Room 1	18	15	Room 1	18
Room 2	18	15	Room 2	18	15	Room 2	18
Room 3	18	15	Room 3	18	15	Room 3	18
Room 4	18	15	Room 4	18	15	Room 4	18
Room 5	18	15	Room 5	18	15	Room 5	18
Room 6	18	15	Room 6	18	15	Room 6	18
Room 7	18	15	Room 7	18	15	Room 7	18
Room 8	18	15	Room 8	18	15	Room 8	18
Room 9	18	15	Room 9	18	15	Room 9	18
Room 10	18	15	Room 10	18	15	Room 10	18
Room 11	18	15	Room 11	18	15	Room 11	18
Room 12	18	15	Room 12	18	15	Room 12	18
Room 13	18	15	Room 13	18	15	Room 13	18
Room 14	18	15	Room 14	18	15	Room 14	18
Room 15	18	15	Room 15	18	15	Room 15	18
Room 16	18	15	Room 16	18	15	Room 16	18
Room 17	18	15	Room 17	18	15	Room 17	18
Room 18	18	15	Room 18	18	15	Room 18	18
Room 19	18	15	Room 19	18	15	Room 19	18
Room 20	18	15	Room 20	18	15	Room 20	18
Room 21	18	15	Room 21	18	15	Room 21	18
Room 22	18	15	Room 22	18	15	Room 22	18
Room 23	18	15	Room 23	18	15	Room 23	18
Room 24	18	15	Room 24	18	15	Room 24	18
Room 25	18	15	Room 25	18	15	Room 25	18
Room 26	18	15	Room 26	18	15	Room 26	18
Room 27	18	15	Room 27	18	15	Room 27	18
Room 28	18	15	Room 28	18	15	Room 28	18
Room 29	18	15	Room 29	18	15	Room 29	18
Room 30	18	15	Room 30	18	15	Room 30	18
Room 31	18	15	Room 31	18	15	Room 31	18
Room 32	18	15	Room 32	18	15	Room 32	18
Room 33	18	15	Room 33	18	15	Room 33	18
Room 34	18	15	Room 34	18	15	Room 34	18
Room 35	18	15	Room 35	18	15	Room 35	18
Room 36	18	15	Room 36	18	15	Room 36	18
Room 37	18	15	Room 37	18	15	Room 37	18
Room 38	18	15	Room 38	18	15	Room 38	18
Room 39	18	15	Room 39	18	15	Room 39	18
Room 40	18	15	Room 40	18	15	Room 40	18
Room 41	18	15	Room 41	18	15	Room 41	18
Room 42	18	15	Room 42	18	15	Room 42	18
Room 43	18	15	Room 43	18	15	Room 43	18
Room 44	18	15	Room 44	18	15	Room 44	18
Room 45	18	15	Room 45	18	15	Room 45	18
Room 46	18	15	Room 46	18	15	Room 46	18
Room 47	18	15	Room 47	18	15	Room 47	18
Room 48	18	15	Room 48	18	15	Room 48	18
Room 49	18	15	Room 49	18	15	Room 49	18
Room 50	18	15	Room 50	18	15	Room 50	18
Room 51	18	15	Room 51	18	15	Room 51	18
Room 52	18	15	Room 52	18	15	Room 52	18

Stage 3 - Ventilation Heat Loss					
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Design Room Temperature	21
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Outside Design Temperature	-3
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Design Temperature Difference	24
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Ground Reference Temperature	6.5
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No. of ach for open flues and chimneys	0				0	0	0	0
--	---	--	--	--	---	---	---	---

6	6.364	3.2	2.36	246.905	0.33	24	1955.49
0				0	0	0	0

Stage 4 - Fabric Heat Loss	Thermal Bridging Addition	
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Thermal Bridging Addition

|--|

Stage 5 Design heat loss and estimated annual energy usage for room	2397.35
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		Reheat factor			Factor if YES	
Period of disues		Up to 11 hours		High ceiling?	0	2397.35
Building air permeability		High		Intermittant heating?	1.2	2876.82
Building mass		Low				

[illegible]

Appendix B.23 – u) Corridor Calculation

ASHP System Design – Room Heat Loss Calculation Work Sheet

Building Details

Building Date:

Location:

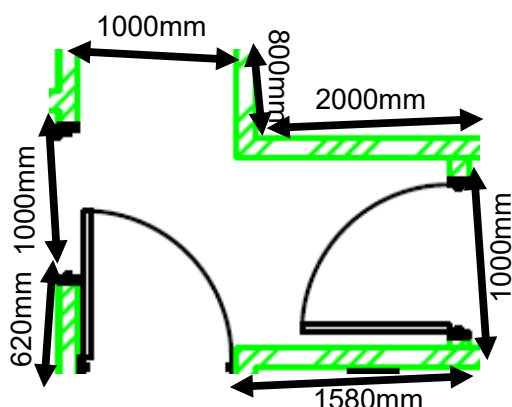
Outside design temperature -3 °C
Ground reference temperature 6.5 °C
Room Design Temperature 21 °C
Design air changes per hour 6 ach

Room details:

Building Element	Construction	U Value W/m ² k
External Wall	Stone aggregate finish, duplex plasterboard with a painted finish, solid sheet insulation set into a timber frame.	0.35
Roof	Profile steel composite insulated sheeting, plastic coated steel, galvanised steel beams and purlins, 5° slope.	0.12
Windows	White UPVC. Window incorporate trickle ventilation, have stainless steel friction hinges and lockable espagnolette handles. Inner reveals have UPVC angle to top side with cellular PVC cill boards. Glazing generally double glazed units with 4mm E float inner, 16mm cavity and 4mm float outer.	2.3
Internal doors	Single door c/w fixed side panel, nominal dimension x 2090mm. Door to allow 1000mm clear opening. Both are double glazed above and below mid rail. Glazing comprises 6.4mm clear laminated outer pane/Argon filled 16mm cavity & thermally broken spacer bar/6.4mm clear laminated i-plus low E soft coated inner pane. Hook type cylinder deadlock, stainless steel cranked pull handle.	3.7
Internal wall	Internal partitioning is of staggered timber stud work construction, with an outer face of decorated plasterboard and inner layer of standard plasterboard. Partitions to run underside of roof deck. The plasterboard sheet joints are taped and flush filled. Estimated db rating = 40.	1.92
Floor	600x600xmin100h concrete pad foundations on tarmac.	0.9

Room Dimensions

Ceiling Height: 2.36 m
High ceiling factor: 0 m



Heat Loss Calculation																
Stage 1 - Job Information																
Room	Corridor		Job	ASHP		Page	1	of	u)							
Stage 2 - Design Temperatures			Stage 3 - Ventilation Heat Loss													
Design Room Temperature	21		ach - No. of air changes per hour	Length (m)	Width (m)	Height (m)	m3/h - Amount of air heated per hour	W/m3K - Air change factor	oC - Design Temperature Difference	Watts - Heat Loss						
Outside Design Temperature	-3															
Design Temperature Difference	24															
Ground Reference Temperature	6.5															
No. of ach for open flues and chimneys																
			6	1.8	3	2.36	53.808	0.33	24	426.159						
			0				0	0	0	0						
Stage 4 - Fabric Heat Loss			Thermal Bridging Addition													
			Length (m)	Width (m)	Height (m)	Area (m2)	U Value (W/m2K)									
External wall (gross area)(length outside x height)											0	0	0			
Glazing											0	0	0	2.3	24	0
External doors											0	0	0	3.7	24	0
Net area of external wall (glazing and door areas subtracted)													0	0.35	24	0
Ceiling or roof (gross areas)			1.8	3		3.132										
Roof glazing			0	0		0	0	0	0	0						
Net area of ceiling of roof (glazing area subtracted)						3.132	0.12	24	9.02016							
Internal Wall 1			1.58			2.36	3.7288	1.92	0	0						
Internal Wall 2			0.62			2.36	1.4632	1.92	0	0						
Internal Wall 3			0.18			2.36	0.4248	1.92	0	0						
Internal Wall 4			0.6			2.36	1.416	1.92	0	0						
Internal Wall 5			2			2.36	4.72	1.92	0	0						
Floor (gross area)			1.8	1		1.8	0.9	14.5	23.49							
			2	1		2	0.9	14.5	26.1							
										49.59						
										58.6102						
Stage 5 Design heat loss and estimated annual energy usage for room										484.77						
Reheat factor			Factor if YES													
Period of disues	Up to 11 hours		High ceiling?		0				484.77							
Building air permability	High		Intermittant heating?		1.2				581.723							
Building mass	Low															
Reheat time:			Reheat facto		Heat-up power											
	0.5 hour	83	315.4													
	1 hour	47	178.6													
	2 hour	25	95													
	3 hour	14	53.2		TOTAL FOR ROOM											
	4 hour	8	30.4		581.723											
	5 hour	3	11.4													
Heat emission (W/m2)(total loss per unit floor area) including down loss										153.085						