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LIFE CYCLE COST ANALYSIS FOR SELECTING HVAC SYSTEMS IN HUDDERSFIELD'S TERRACE HOMES

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TABLE OF CONTENTS

TABLE OF CONTENTS 3
LIST OF TABLES 7
LIST OF FIGURES 8
ABSTRACT 9
CHAPTER 1: INTRODUCTION 10
1.1 INTRODUCTION. 10
1.2 PROBLEM STATEMENT. 11
1.3 RESEARCH QUESTIONS. 13
1.4 RESEARCH AIM & OBJECTIVES. 14
1.4.1 Research aims. 14
1.4.2 Objectives. 15
1.5 RESEARCH METHODS. 16
1.5.1 Qualitative Data Collection. 16
1.5.2 Quantitative Data Collection and Analysis. 16
1.6 EXPECTED RESULTS & PROJECT PROPOSAL 18
1.6.1 Expected results. 18
1.6.2. Project proposal. 18
1.7 LIMITATIONS. 20
1.8 ETHICAL CONSIDERATIONS. 21
1.9 RESEARCH TIMEFRAME. 22
CHAPTER 2: LITERATURE REVIEW 23
2.1 INTRODUCTION. 23

2.2 HOUSE OVERVIEW. 24
2.3 OVERVIEW OF HVAC SYSTEMS. 27
2.3.1 Type of Fuel 27
2.3.2 Types of HVAC systems 28
2.3.3 HVAC system options 34
2.4 LIFE CYCLE COST ANALYSIS. 38
2.4.1 Life Cycle Cost method overview (RICS, 2016) 38
2.4.2 Importance of Life Cycle Costing method 41
2.4.3 The Effect of Life Cycle Cost method 41
2.4.4 Relevant costs and cost data structures (RICS, 2016) 42
2.5 ENERGY EFFICIENCY STANDARDS AND REGULATIONS. 43
2.5.1 Common regulatory requirements 43
2.5.2 System-specific requirements 45
2.5.3 Local Contractor Requirements 46
2.5.4 Key differences between options 47
CHAPTER 3: METHODOLOGY / PROJECT 48
3.1 HOUSE OVERVIEW. 48
3.2 INSULATION CALCULATIONS AND DEPLOYMENT PLAN 54
3.2.1 Introduction 54
3.2.2 Material selection 54
3.2.3 Calculation details 54
3.2.4 Deployment plan 57
3.2.5 Expected result 59
3.3 BUFFER TANK SIZING. 61
3.3.1 Buffer Tank sizing overview 61

3.3.2 Buffer Tank sizing calculation 62

3.3.3 Buffer Tank sizing choice. 62

CHAPTER 4: RESULT & DISCUSSION 63

4.1 WEATHER TRENDS AND HVAC IMPLICATIONS. 63

4.2 LIFE CYCLE COST ON HVAC SYSTEMS. 66

4.2.1 Energy usage and cost annually 66

4.2.2 Life Cycle Cost Assessment method. 68

4.3 DISCUSSION. 71

CHAPTER 5: CONCLUSION 73

REFERENCES 76

APPENDIX

A. Timeline Gannt chart

B. Wall area calculation excel file

C. Life Cycle Cost assessment excel file

D. Weather trend sketch

LIST OF TABLES

Table 1. Comparison of HVAC system 33

Table 2. System option comparison 37

Table 3. HVAC option comparison 47

Table 4. Ventilation, ductwork and extraction 53

Table 5. The external and internal wall area 56

Table 6. Life Cycle Costing Assessment 69

LIST OF FIGURES

Figure 1. Timeframe information........ 22

Figure 2.Timeframe - gantt chart........ 22

Figure 3. Title plan. Source: HM Land Registry........ 24

Figure 4. EPC. Source: GOV.UK........ 25

Figure 5. Property breakdown. Source: GOV.UK........ 26

Figure 6. Combi boiler Diagram. Source: Worcester Bosch........ 30

Figure 7. Ductless mini-split system diagram........ 32

Figure 8. HMO license........ 49

Figure 9. Energy usage........ 49

Figure 10. Floor plan........ 50

Figure 11. Boiler........ 51

Figure 12. Boiler pipe........ 51

Figure 13. Boiler when working........ 52

Figure 14. Bradford weather trend........ 63

Figure 15. AC need assessment........ 64

ABSTRACT

This dissertation examines the selection of an optimal HVAC system for a middle-stained house in the Hudersfield through the Life Cycle Cost (LCC) analysis. Facing the challenges of unexpected weather and aging construction fabrics, the purpose of the study is to evaluate various heating, ventilation and air conditioning options in terms of initial installation, operation, maintenance and disposal costs. Primary data, which is taken from an interview with the landlord and complemented by tenant surveys, provides the required insight into the construction and current performance.

A mixed-methods approach is applied, combining quantitative technical calculations (including insulation area assessment and buffer tank size) with qualitative input to assess energy efficiency and economic viability. The LCC analysis structure facilitates a detailed comparison of potential HVAC systems, including a decrease in energy consumption obtained through targeted insulation upgrade process. Although the final system selection remains open, the evaluation is designed to inform a decision that balances cost-efficiency with environmental stability.

Preliminary findings suggest that while traditional gas-based systems can offer low upfront costs, alternative technologies can provide better long-term economic and stability benefits. Research contributes to practical guidance to owners and decision-makers of property, which navigates the HVAC system improvement in old residential buildings in serious weather conditions, ensure a balanced approach that prefer both immediate performance and long-term flexibility. (gorge, 2020)

CHAPTER 1
INTRODUCTION

1.1 Introduction.

It has been a known fact the weather in the United Kingdom is infamously unpredictable and extreme (Met Office, 2022). Furthermore, the adverse effect of climate change including heatwaves had resulted in the health and well-being of the residents who live in the region (IPCC, 2021). There have been numerous papers investigating the problem, along with solutions, in which one of them being the implementation of HVAC (Heating, Ventilation, and Air Conditioning) systems (Sadur et al, 2019).

This research will focus on the mid terrace house in Huddersfield, with the housing condition shown to have aging signs and requires modernization, making the local people unable to find a suitable and comfortable living space (Savills, 2023). The place is located in the Northen region of the UK, known for experiencing severe weather conditions as well (Met Office, 2022). The study will investigate different HVAC systems and select the most appropriate one by integrating the Life Cycle Costing (LCC) method into the decision-making process.

1.2 Problem Statement.

Which is the most appropriate HVAC system for a terrace house located in a severed weather neighborhood, and how can installing it be beneficial for the landlord in terms of cost-effectiveness?

Despite being present for a long period of time in Europe, the HVAC systems are not widely known in England. There are several factors that contribute to this phenomenon, both from consumer perception as well as practical implementation. UK residents' belief that it is unnecessary to have such systems in the colder weather, as they prefer a house that retains heat (Victor, 2022). The misconception is formed as people mistook the HVAC systems for the AC systems only, proving coolness to the apartment in the warmer period. The installation is also a challenge as the process expects several modifications of the given infrastructure, containing ventilation system, ductwork and electrical systems (Mid-Tech Services Limited, 2023), demanding professionals and expertise in the field. In addition, the system itself is an investment as well. Hence, homeowners and developers are greatly discouraged from investing in such systems, especially in an economic environment where cost savings and energy efficiency are critical factors (Jones & Smith, 2021).

The selection of Heating, Ventilation and Air Conditioning is important to ensure comfort and energy efficiency, especially in areas affected by severe weather. This study is dedicated to evaluating the most appropriate HVAC systems for terrace houses using Life Cycle Cost (LCC) method. The method provides a comprehensive method to evaluate not only the installation cost but also the operational and maintenance cost in the future. The primary research question is: Which HVAC system offers optimal performance and cost-effectiveness for a terrace house in a severe weather neighborhood? Furthermore, the study seeks to explore how the HVAC system can beneficial the landlord in terms of cost-efficiency, energy efficiency and increase the property value.

1.3 Research Questions.

Question 1:

- What are the layout and the size of the house?
- What is the insulation quality and the number of windows of the house?
- What is the standard of the HVAC systems?
- What are the suitable HVAC systems for the house
- What are the regulations and standards that must be followed when implementing the systems?

Question 2:

- What is Life cycle costing method?
- What is the effect of LCC on the process of installing the HVAC systems?
- What are the criteria to use when evaluating the systems?
- What are the steps for installing the HVAC systems?
- What is the expense projection of the final budget?

Question 3:

- What are the criteria to compare?
- Which is the most appropriate HVAC system?
- What are the features of each system?

1.4 Research aim & objectives.

1.4.1 Research aims.

This dissertation aims to contribute insights of selection of HVAC systems within the specific context of Huddersfield weather. The outcome of this research will contribute valuable insights into the selection of HVAC systems that are not only suitable for severe weather conditions but also economically advantageous over the lifespan of the system.

Addressing the issue, the researcher will talk about the Life Cycle Cost method as a technique to evaluate the economic aspects and optimize the capital of the investment in long-term. The evaluation contains different aspects including:

1. Initial Costs
2. Operating Costs
3. Maintenance and Repair Costs
4. Replacement Costs
7. Energy and Water Costs
8. End-of-Life Costs
9. Discount Rate and Inflation

The research will compare two HVAC systems, and the result will be carried out after consideration of comparison between the systems. The study will be informed by a detailed analysis of standards of HVAC system for smaller buildings, while selecting and analyzing features according to those specific standards.

1.4.2 Objectives.

1. Identifying systems suitable for terrace house: assessing existing HVAC systems to identify common practices
2. Analyzing the mentioned systems using LCC method: utilize the LCC method to compare the mentioned systems based on the cost
3. Finalizing on appropriate HVAC system: recommend the most suitable one tailored for the specific needs

1.5 Research Methods.

This study adopts a mixed-method approach to check energy efficiency upgradation and HVAC system selection for a mid-thread house in the bone. The functioning combines quantitative evaluation, detailed technical calculations and qualitative insights to ensure the comprehensive evaluation of the project. The major components of functioning are as follows:

1.5.1 Qualitative Data Collection.

1.5.1.1 Landlord Interview

An interview was held with the landlord to collect important background information about the house. This included details on the original construction, historical use pattern, current occupants and existing heating systems. The insights of this interview provided the necessary references and later directed the technical analysis and system selection criteria.

1.5.1.2 Tenant Survey

A brief questionnaire was administered among the tenants to assess the demand for air conditioning. This reaction affected the decision criteria to select the HVAC system capable of addressing both heating and future cooling requirements.

1.5.2 Quantitative Data Collection and Analysis.

1.5.2.1 Insulation Calculation and Deployment Plan

Field measurements and architectural plans were used to calculate insulation areas for attic/roof, external and internal walls and floors. The specific insulation material was chosen based on the preference of the landlord as well as the necessary performance of the project. Detailed cost estimates were made using standardized formulas that account for field, layer factors and unit prices.

1.5.2.2 Buffer Tank Size

The suitable size for hot water buffer tank was calculated to stabilize the HVAC system. Using the ability and estimates of the heat pump of existing water volume in radiators and pipework, the required quantity was determined to reduce the equipment cycling and adapt the performance.

1.5.2.3 HVAC system comparison and life cycle cost (LCC) analysis

Life cycle cost was applied to each option in a period of 10 years. This analysis included construction, operations, maintenance and disposal costs-to determine the long-term economic viability. The LCC functioning provided a holistic approach to the environmental impact of the system with both advanced and ongoing financial implications.

1.6 Expected results & project proposal.

1.6.1 Expected results.

By comparing various criteria and evaluation devices against HVAC standards installed for mid-terrace buildings, research will identify major features that ensure optimal performance, cost-effectiveness and environmental stability.

A detailed comparison of selection criteria will be conducted. This comparison will showcase how each criterion will affect small buildings in Huddersfield.

The project proposes an integrated approach for HVAC system selection, ensuring that mid-terraced buildings can get balance between immediate operating requirements, long -term economic viability and low environmental impacts

1.6.2. Project proposal.

1.6.2.1 Integration of insulation upgrades

Apply targeted insulation on attic, walls and floors based on the calculation and cost evaluation if necessary. This will increase thermal retention and overall energy performance.

1.6.2.2 HVAC System Selection and Implementation

The first option is the gas boiler, ensuring compatibility with the existing radiator system. The second option is heating pump system, emphasizing its dual functionality for heating and potential future cooling through a ductless mini-split configuration. Include the employed buffer tank size to improve the operational stability and efficiency of the heat pump.

Assess economic viability through 10 years of life cycle cost analysis that are factors in construction, operation, maintenance and disposal expenses.

1.7 Limitations.

This study is limited as it focuses on one property only, restricting the generality of findings at other building types or locations. Additionally, the technical and cost calculation (such as insulation performance and future energy prices) are uncertainties which can affect the life cycle cost analysis and overall accuracy of environmental impact estimates.

1.8 Ethical considerations.

While conducting the research, the researcher will acknowledge the following ethical consideration:

1. Voluntary participation: Participant(s) is/are free to opt in an out of the study at any point in time without penalty
2. Informed consent: Participant(s) understand(s) the purpose as well as the benefits and the risks of the study
3. Confidentiality: Participant(s) identity remain(s) unknow if they wish to
4. Potential for harm: Any physical, social, psychological, and all other types of harm are kept to an absolute minimum
5. Results communication: The research is free of plagiarism or research misconduct

1.9 Research Timeframe.

		Name	Duration	Start	Finish	Predecessors
1		Topic Defining	7 days	10/10/24 8:00 AM	10/18/24 5:00 PM	
2		Documentation & Planning	64 days	10/21/24 8:00 AM	1/16/25 5:00 PM	1
3		Landlord Interview & Tenant Survey Distribution	3 days	10/31/24 8:00 AM	11/4/24 5:00 PM	2SS+7 days
4		Data Collection & Verification	74 days	11/5/24 8:00 AM	2/14/25 5:00 PM	3SS+1 day
5		Insulation Deployment Plan & Technical Calculations	15 days	1/6/25 8:00 AM	1/24/25 5:00 PM	2SS+27 days
6		Buffer Tank Sizing & Detailed HVAC Technical Analysis	40.5 days	1/15/25 8:00 AM	3/12/25 1:00 PM	5SS+7 days
7		Preliminary Life Cycle Cost (LCC) Analysis	12 days	2/26/25 8:00 AM	3/13/25 5:00 PM	6SS+30 days
8		Data Integration & Chapter Drafting (Results & Discussion)	57 days	12/4/24 8:00 AM	2/20/25 5:00 PM	4SS+14 days
9		Refinement, Revisions & Formatting of Chapters	28 days	1/27/25 8:00 AM	3/5/25 5:00 PM	8FF-10 days
10		Final Editing, Proofreading & Submission Preparation	21 days	2/20/25 8:00 AM	3/20/25 5:00 PM	9FF-39 days

Figure 1. Timeframe information

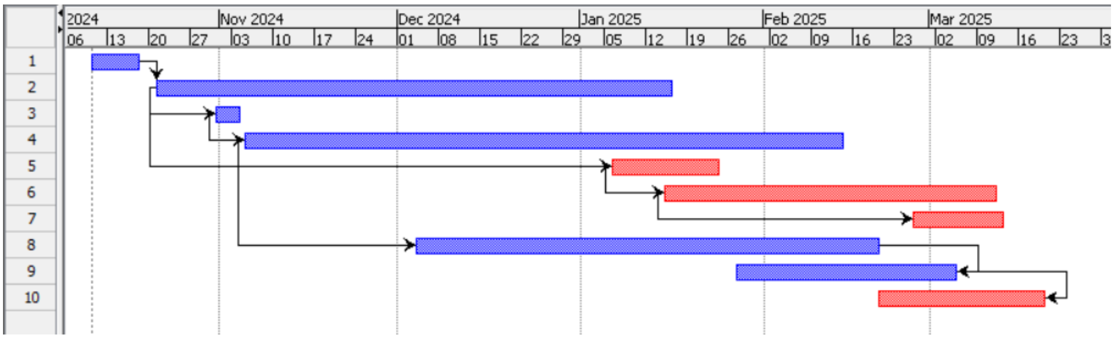

Figure 2.Timeframe - gantt chart

Detailed timeline can be found in the supplementary file (see Appendix).

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction.

The United Kingdom encounters an unpredictable weather pattern, which is affected by climate change, challenging the traditional building practices. To address the problem, upgrading the heating, ventilation, and air conditioning (HVAC) systems has become an important focus, increasing both indoor comfort and energy efficiency. This study examines the possible benefits of modernization of HVAC solutions through an economic assessment using the life cycle cost (LCC) method. The analysis will consider a series of HVAC technologies that offer both heating may or may not have the cooling capabilities. Instead, these systems will be evaluated against the same criteria including installation compatibility, operational efficiency and adaptation capacity for the position of separate buildings, such as poor thermal performance of walls.

By integrating technical assessment with LCC analysis, research aims to identify cost -effective and durable HVAC options suitable for old residential buildings. This approach not only addresses the need to improve energy performance in the face of extreme weather conditions, but also supports the long - term economic plan, aligning with widespread environmental stability goals.

2.2 House overview.

The residential structure selected for this case study is a 4 story mid-terrace house nestled in a suburban neighborhood. The house was built around the 1920s with minimal to no insulation in between the walls, which makes it particularly suited for research. The property is located at 3, Smithy Lane, Moldgreen, Huddersfield, HD5 9AP, United Kingdom.

Figure 3. Title plan. Source: HM Land Registry

According to the Energy performance certificate (EPC) of the building, the property's energy rating is D (55D), but it has the potential to be C (78C). Properties get a rating from A (best) to G (worst) on how much carbon dioxide (CO_2) they produce each year.

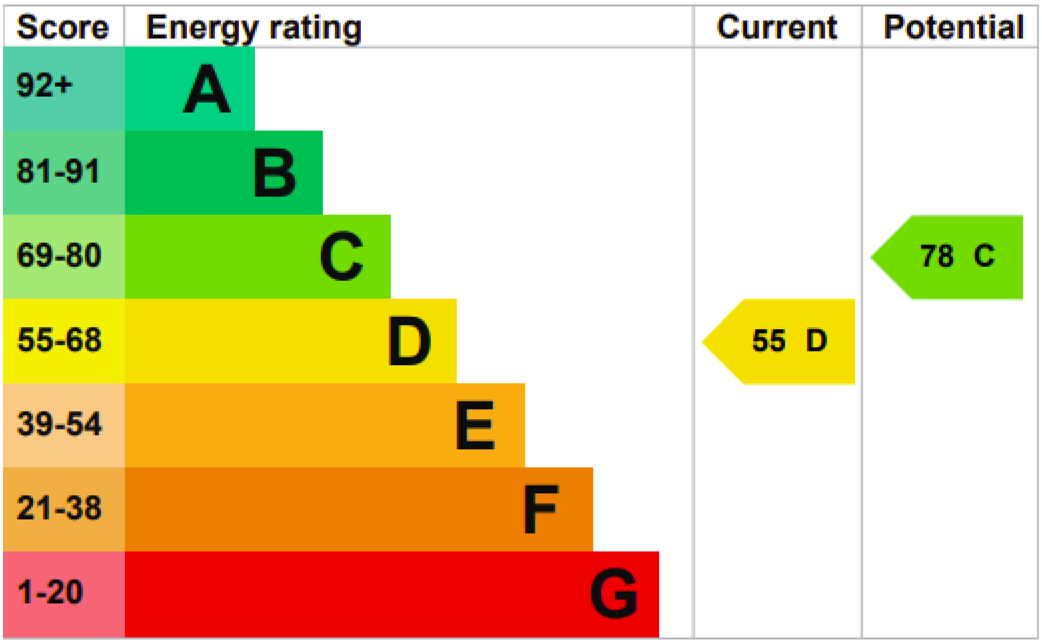

Figure 4. EPC. Source: GOV.UK

The primary energy use for this property per year is 289-kilowatt hours per square meter (kWh/m2). Estimated energy needed in this property is 30,062 kWh per year for heating and 2,334 kWh per year for hot water.

(Note: Primary energy use is a measure of the energy required for lighting, heating and hot water in a property. The calculation includes: the efficiency of the property's heating system; power station efficiency for electricity; the energy used to produce the fuel and deliver it to the property)

A breakdown of rating in the property

Features in this property

Features get a rating from very good to very poor, based on how energy efficient they are. Ratings are not based on how well features work or their condition.

Assumed ratings are based on the property's age and type. They are used for features the assessor could not inspect.

Feature	Description	Rating
Wall	Sandstone or limestone, as built, no insulation (assumed)	Poor
Roof	Roof room(s), no insulation (assumed)	Very poor
Window	Mostly double glazing	Average
Main heating	Boiler and radiators, mains gas	Good
Main heating control	Programmer, TRVs and bypass	Average
Hot water	From main system	Good
Lighting	Low energy lighting in all fixed outlets	Very good
Roof	(another dwelling above)	N/A
Floor	Solid, no insulation (assumed)	N/A
Floor	(another dwelling below)	N/A
Secondary heating	None	N/A

Figure 5. Property breakdown. Source: GOV.UK

An average household would need to spend £1,829 per year on heating, hot water and lighting on this property. These costs usually make up the majority of the energy bills.

2.3 Overview of HVAC Systems.

HVAC system stands for Heating, Ventilation, and Air Conditioning. It is designed to temperature, humidity, and air quality within enclosed spaces such as homes, offices, and other buildings. The heating units have a furnace that burns fuel like natural gas or oil. It includes boilers for water heating systems. And the facture of the company which is to raise indoor temperatures during colder weather. The ventilation systems are used to exchange indoor and outdoor air. Normally, it also includes filtration systems to remove contaminants and essential for maintaining proper air quality. The air condition units contain compressors, condensers, and evaporators. It uses refrigerant for heat exchange. The HVAC system has a solid impact on the environment. They filter out the pollutants and contaminants, controls humidity levels and contributes to lower energy consumption.

2.3.1 Type of Fuel

There are 5 different types of fuel. The most popular choice in urban areas for heating is natural gas. The fuel typically provides a reliable and consistent heat source, as well as being efficient and cost-effective. However, the downside of it is the fluctuation in gas prices which can impact overall heating costs. Unlike the gas-based heating system, the electric heating systems are particularly effective in smaller homes or where gas lines are not available. They are also favored as they are easy to install and require less maintenance. On the other hand, the cost for electricity is higher compared to gas, depending on local rates, and its environmental impact varies based on how the electricity is generated. For a traditional heating method, wood-burning stoves are biased. Not only do they provide a cozy atmosphere but also often considered more environmentally friendly if sourced sustainably. However, they are not suitable for the urban setting. In contrast, coal heating is often criticized for its pollution and carbon footprint, hence it is more likely to raise environmental concerns as it is hard to find cleaner alternatives. Furthermore, the system requires more maintenance and fuel sourcing. Lasty, using water to distribute heat, the hydronic heating systems can be powered by various fuels, including gas, electricity, or wood. They are impressed by their efficiency and comfort, providing even heat distribution. However, the initial installation cost can be higher compared to other systems.

Given that the case study pertains to a mid-terrace house, the selection of HVAC systems is significantly influenced by this architectural characteristic. Natural gas is the most favored for their balance of cost, efficiency, and availability aspect; while the electric heating system is more suitable for smaller areas or places where gas lines are not present. In this report, the researcher will choose two systems which are gas fuel-based and electricity-based.

2.3.2 Types of HVAC systems

2.3.2.1 Gas Combi Boiler with Radiators

For the gas heating system, the most popular one for mid-house terrace is a gas combi (combination) boiler. It is powered by natural gas on propane, producing carbon dioxide (CO2). Although it burns cleaner than coal or oil, it is still a fossil fuel and emits greenhouse gases, which contributes to global warming (Bevan, 2024). However, due to its popular characteristic of compacting and efficient providing both central heating (via radiators) and hot water on demand, without the need for a separate water tank or cylinder. This is highly favored in a smaller area as it does not take up much space (box, 2023).

This system operates by 2 components in the boiler, which are the primary heat exchanger for radiators heat, and secondary heat exchanger for hot water. To heat the water for the radiators, the boiler uses the primary heat exchanger from the central heating system. This water circulates through the pipes under the radiators. The hot water transfers into heat which warms the room (Heating, n.d.). After circulating around the house, the water cools down. Hence, it needs to be returned to the boiler to be reheated and recirculated before starting another round (Ltd & Elston, 2024). Another part, which is the secondary heat exchanger in charge of providing hot water. When the tap water or shower is turned on, the boiler will receive it as a sign and start heating fresh water. The system transfers heat to the water, ensures instant hot water is available without the need for installing a storage tank (Morgan, 2018). The main energy for the boiler is natural gas or propane. They are burnt to generate heat, which is transferred to the water in the system. This water then serves as heat for the radiators or hot water for the tap or shower depending on the need. The combi boiler is compacted as it combines the functions of a water heater and a central heating boiler into a single unit, making it a room-saving design, ideal with projects such as the mid-terrace house where space is limited.

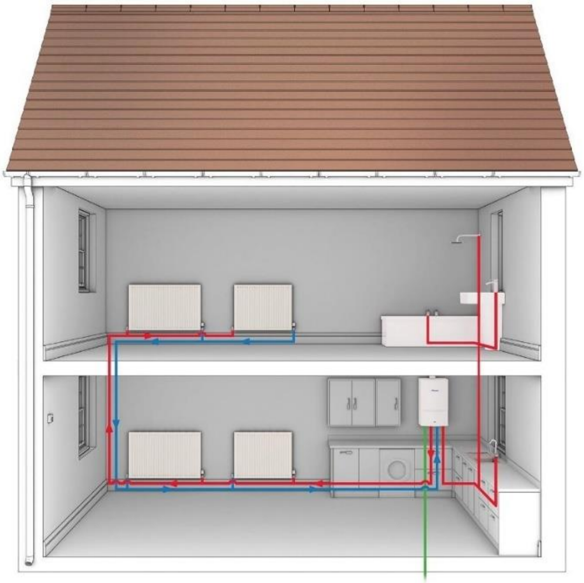

Figure 6. Combi boiler Diagram. Source: Worcester Bosch

In summary, the Gas combi boiler has some benefits for the mid-terrace house. Unlike traditional systems, modern combi boilers are also highly efficient, with most achieving over 90% efficiency, as they convert most of the gas they burn into usable heat. This efficiency enables the system to heat water directly from the mains source, ensuring that hot water is instantly available whenever needed — without waiting for a tank to warm up. This compact design makes it particularly suitable for smaller homes, making it an ideal choice for households with moderate water usage. The boilers are also convenient to implement as they work well with standard radiator systems, which are common in mid-terrace homes. Lastly, as they are typically wall-mounted, combi boilers are ideal for smaller properties where space is at a premium.

2.3.2.2 Ductless Mini-Split System

The mini-split system is an electric heating system that provides both heating and cooling for the house. It is highly efficient and allows control of the temperature in individual rooms or areas. It consists of two main components, including an outdoor compressor or condenser unit and several indoor air-handling units, which are often wall-mounted. These units are connected through refrigerant lines and electrical wiring, which are wrapped in a conduit.

The system operates by two units, the condenser (outdoor unit) and the air handler (indoor unit). The outdoor unit is responsible for compressing and circulating refrigerant. By doing that, it absorbs heat from inside the home and releases it outside in cooling mode, and in heating mode, it works in reverse, extracting heat from the outside air, even in cold weather, and transferring it indoors. The refrigerant is carried through insulated refrigerant lines. They contain a suction line and a liquid line. These two lines are both used for carrying refrigerant back and forth between the units. However, the suction line is used to carry low-pressure refrigerant gas back to the compressor while a liquid line that carries high-pressure liquid refrigerant to the indoor unit. The indoor unit contains evaporator coils that are cooled, in cooling mode, or heated, in heating mode, by the refrigerant. Warm air from the room is drawn into the unit, where it passes over the coils. The refrigerant absorbs heat from the air inside in the evaporator coil, then brings it to the outdoor unit. From this unit, the heat is released into the outside air. This process can also be in reverse, depending on whether it is a heating mode or cooling mode. Meanwhile, electrical wiring is used to communicate between indoor and outdoor units as it connects them. The operation of different components such as compressors and fans is regulated due to the transmission of signals that are controlled by this wiring. Additionally, this wiring provides power to the indoor units, which allows them to operate independently while still being part of the overall system.

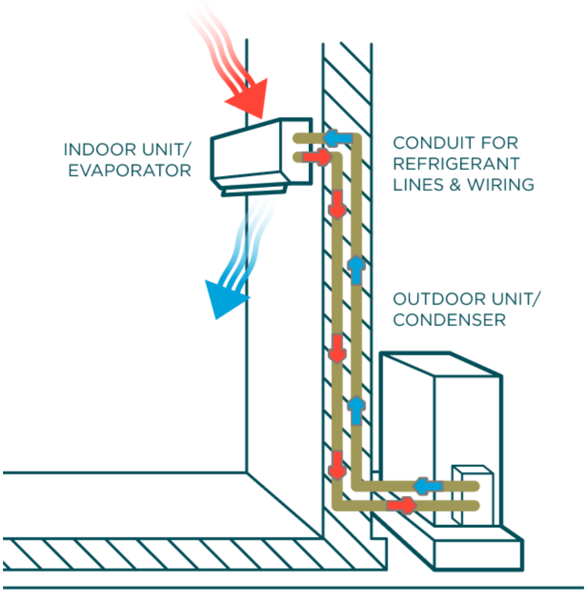

Figure 7. Ductless mini-split system diagram

The ductless mini-split system is also highly energy efficient. As mentioned in the name, the system does not operate using duct work, which lessens the work for installing, does not take a lot of space and ultimately avoids energy losses from it. A huge advantage It allows each indoor unit to operate independently; hence different temperatures can be set in different zones. This can become convenient as unused space does not require heating or cooling.

In summary, the Mini-spilt ductless system has several aspects that would suit the building in the case study. The system can function as both an air conditioner and a heat pump, making it suitable for year-round operation rather than being limited to use only during the colder months. The heat from the system is provided by moving the air rather than generating it, which is highly energy efficient. The indoor units are controlled independently; hence the temperature can be set independently, satisfying the users. Last, the design will take up less space as they are ductless, and they are mounted to the wall. Also, it is recommended to mount the units higher rather than lower to the floor, which makes it less likely to create obstacles within reach.

2.3.2.3 HVAC comparison

Table 1. Comparison of HVAC system

Feature	**Gas Combi Boiler with Radiators**	**Ductless Mini-Split System**
Pros		
Lower Installation Costs	Generally cheaper to install (£1,500 to £3,000)	Higher installation costs (£4,000 to £8,000)
Reliable Heating	Provides consistent and powerful heating, ideal for colder climates	Provides both heating and cooling
Compact Design	Space-saving design; no separate water tank or cylinder required	Wall-mounted units may not appeal to everyone
Widely Available Fuel	Natural gas is widely available and often cheaper than electricity	Highly efficient, with SEER ratings often exceeding 20 Zoned heating and cooling, reducing energy waste Lower operating costs in many cases, especially with renewable energy sources Future-proof as it aligns with electrification and renewable energy policies

Cons		
Higher Operating Costs in Future	Gas prices expected to rise due to taxes and decarbonization efforts	Higher upfront costs may deter some homeowners
Environmental Concerns	Relies on fossil fuels, contributing to carbon emissions; many governments phasing out gas boilers	Requires good insulation for optimal performance
Cooling Capability	None as only heating feature provided; separate system needed for cooling	
Future Cost-Effectiveness	Long-term viability is questionable due to rising gas prices and environmental regulations	More cost-effective in the long term due to energy efficiency and dual functionality

2.3.3 HVAC system options

2.3.3.1 Worcester Bosch Green Star 4000 Range (Gas boiler)

The Worcester Bosch Green Star 4000 Range is an A-rated gas boiler for energy efficiency, which helps reduce energy bills, therefore is cost-effective. The system is referred to as “perfect for small to medium-sized homes with one bathroom” according to (Worcester, 2021) as it boasts an impressive 94% energy efficiency rating. The design "SimpleSwitch" simplifies the process of replace and reinstall, which is beneficial as it minimizes the potential of time wasting, as well as wrongly installed in terms of misplacing, misassembling, etc. Furthermore, it is a wall-mounted system, which is suitable for limited areas. As the original heating system is a gas boiler, there are not much different when changing to the new system. A plan has been considered to improve the EPC rating from 55D to 70C. Incorporating an energy-efficient boiler like the Greenstar 4000 would greatly enhance these efforts and provide significant benefits.

2.3.3.2 The Earth Save Product Green Line 22kW (Heat pump)

The Earth Save Product Green Line 22kW is a modern air source heat pump with a wide range of temperature delivering. The machine uses the refrigerant R290 for heating and cooling purposes, which is environmentally friendly as it has a lower global warming potential compared to some alternatives. A standout feature of the system is that it is guaranteed to efficiently perform even during harsh winter days. This is particularly relevant in Huddersfield's cooler climate. The Greeb Line has the heating capacity of 22kW, ensuring that the property's heating and domestic hot water demands will be met comfortably. The system is also keen on renewable and lower carbon footprint, which is one of the main focused goals of this project. As the property currently relies heavily on gas (with 37,285 kWh annual consumption) and energy efficiency improvements, installing the the Green Line will benefit the process of "going green". Using the system will reduce fossil fuels as it not only lowers carbon emissions but can also contribute to improved EPC ratings over time. In order to utilize the Green Line, an insulation process will be integrated, which then lowered the heat demand. The system can operate more efficiently as it benefits from reducing heating loads. Because of the higher efficiencies and the lower cost of electricity relative to gas when considered, the running costs tend to be lower over the lifespan of the system. Changing from a gas source-based system into an electric source-based system will foster the energy savings process in the long run. The Green Line system that is only efficient heating but also compatible with the original standard radiators. For heat output stabilization, the system can be integrated with suitable tanks (e.g., a 200L buffer tank) to prevent frequent cycling and reduce mechanical stress on the compressor.

The Earth Save Products (ESP) 200L Hot Water Buffer Tank helps prevent the heat pump from cycling on and off too frequently. As frequent cycling can lead to increased wear on the compressor and reduced efficiency over time, the system is extremely useful when paired with a heat pump. The buffer tank will support smoother operations and improved performance. It will also ensure the heat pump runs in longer, more efficient cycles rather than short bursts of activity. The system has a design for floor standing, meaning that the installation would be less complicated as there is no wall-mounting or fitting. The design also contains multiple connection points, allowing smoother process when rewiring to the existing system. The tank has a feature of limiting the on/off cycling of the heat pump to reduce mechanical stress on the system. This resulted in lower maintenance costs as well as fewer unexpected breakdowns.

2.3.3.3 HVAC system option comparison

Table 2. System option comparison

Feature	The Earth Save Product Green Line 22kW	Worcester Bosch Greenstar 4000
Type of Unit	Air Source Heat Pump (ASHP)	Gas Combi Boiler
Unit Size	Available in 9kW, 15kW, and 22kW models	Available in 25kW and 30kW models
SEER Value	High efficiency (SCOP > 4.0)	Efficiency of around 94% (A-rated)
Brand of Unit	EPS	Worcester Bosch
Environmental Impact	Low GWP refrigerant (R290)	Relies on natural gas, higher carbon footprint
Running Costs	Generally lower due to high efficiency	Higher running costs due to gas reliance
Suitability for Students	Consistent heating and hot water, ideal for larger demand	Compact, but may struggle with high simultaneous demand

2.4 Life Cycle Cost analysis.

2.4.1 Life Cycle Cost method overview (RICS, 2016)

Life Cycle Cost is the total cost when owning and operating an asset and takes into account all associated costs in its entire lifespan to disposal. Understanding life cycle costs can provide a comprehensive financial viewpoint for an asset investment, which supports the decision-making process and long-term planning.

The Technical Life Cycle (Team, 2023) is the stages in the lifespan of a technology or a product from start to disposal which gives an insight on how it evolves and becomes outdated. Organizations optimize the concept of Technical Life Cycle to plan for product operations, identify opportunities for product development, and implement sustainable practices in the production cycle. The first in the 6-step procedure is research and development (R&D) where the team will generate new ideas and concepts. The process will involve innovation brainstorming, developing early models to test feasibility and functionality, and conducting experiments for product reliability. After testing, the technology will go into the “Introduction” phase where it is launched into the market, along with marketing campaigns and user feedback. “Growth” is the next step where the technology gradually gains traction and market acceptance. The product growth is shown through increased production, market expansion, and continuous improvement based on feedback and technological advancements. The product will reach its 4th stage “Maturity” when it’s at its peak performance in the market. Due to high demand, the company will focus on maintaining profitability through improving efficiency, reducing costs, while dealing with other competitors entering the market. However, over time, the technology will start falling into the “Decline” stage. The market has been saturated as the technology has been well adopted by users and replaced by newer technologies, resulting in the decline of production support from the organization. At the end of the cycle, the technology and/or product will be either disposed of or recycled to maintain the company’s sustainability commitment. In summary, the Technical Life Cycle provides a framework for understanding how technologies evolve, their market dynamics, and the impact for businesses and consumers throughout the life of a product.

The Economic Life Cycle (The Investopedia Team, 2023) refers to the duration when an asset is economically profitable, focusing on the mechanics of loss in 2 primary forms: mechanically induced loss and value loss. Mechanically induced loss is the physical deterioration of an asset due to usage over time. Through its lifespan, the mechanics will decline in quality and performance due to wear and tear, thus, it needs to be repaired or replaced accordingly. Over time, its failure to meet the performance expectations will affect its operational costs and the overall economic viability of continuing to use the asset. The second loss is value loss when taking into account the asset’s depreciation over time. Over time, the product's market value will decline, along with its utility and associated maintenance/production cost. The actual value cost will be quantified by different accounting methods such as straight-line or declining balance depreciation. Additionally, the residential value or the expected value at the end of the asset's life, is also considered in assessing value loss.

The Economic Life Cycle starts when the product is purchased or developed, known as the “Acquisition” stage. The related costs to be considered in this step is the initial costs like purchase price, installation, taxes, etc., and costs relating to financing the acquisition, such as interest on loans. During the “Operation” stage, the team will measure operational costs, including regular expenses like labor costs, and evaluate the asset’s efficiency and reliability. “Maintenance” step requires regular maintenance to ensure efficient lifespan, including routine inspection and unforeseen repairs. Aside from maintenance, assets may also need to be updated in the fourth stage where it takes into account the cost of adding or replacing a product’s components to enhance functionality. “Decommissioning” marks the end of an asset’s useful life, where companies calculate the expenses of removing the assets and handling product waste according to environmental regulations. On the other hand, Economic Life Cycle also includes “Residual Value”, which is the estimated value of an asset at the end of its life cycle to offset the total cost. The Residual Value takes into consideration its impact on LCC, and the compensation made from reselling or recycling the asset, or the “Salvage value”.

When businesses can understand and apply the Economic Life Cycle effectively, they can evaluate the total cost of ownership for investment decision-making, plan for future budgets, determine ROI, and consider long-term economic and environmental impact.

2.4.2 Importance of Life Cycle Costing method

Utilizing Life Cycle Costing is essential in 4 aspects of the decision-making process for an asset investment. First of all, by considering all costs associated with an asset, stakeholders can make more informed decisions about investments, to obtain the best long-term value overtime rather than just choosing the lowest initial cost. Additionally, it also optimizes budget planning to ensure financial resources during the asset's life cycle. Since life cycle costing incorporates environmental impacts, it encourages stakeholders to lean into more sustainable options to align with organizational goals and related regulations. Moreover, the measurement is an effective tool to evaluate and keep track of the asset's performance through different stages and timely identify problems or improvements as needed.

2.4.3 The Effect of Life Cycle Cost method

The Life Cycle Cost (LCC) method plays a critical role in the decision-making process for selecting and installing HVAC systems by providing a comprehensive evaluation of costs incurred over the entire lifespan of a system. The method allows consumers to have detailed examination of the upfront costs associated with equipment and installation before purchasing. This is highly important, especially for a cost-conscious project. For colder places such as Huddersfield where the demand for heat consumption is high, it is essential to evaluate the energy usage and cost. Gas boilers may have relatively lower initial costs, but their higher carbon emissions and dependency on fossil fuels may result in higher operating costs compared to a heat pump system, especially as energy prices shift toward favoring renewable sources. As can be seen, assessing the systems can also be relevant to the environment and energy efficiency, ensure a sustainable decision. The method emphasizes the importance of ongoing maintenance and potential replacement costs. Different systems can have different maintenance processes, as one can be complicated but has a longer lifetime, which can affect the cost in the long term.

2.4.4 Relevant costs and cost data structures (RICS, 2016)

Below is the cost that the researcher will apply to the assessment

- Construction cost (delivery cost, installation cost, material cost)
- Operation cost (energy & water cost)
- Maintenance cost (repair cost once a year)
- Disposal cost
- Discount rate & inflation

Factors that affect HVAC installation cost: (Rosanne Schipper,2024)

- Type of unit
- Unit size
- SEER value
- Brand of unit

2.5 Energy efficiency standards and regulations.

Installing HVAC systems in Huddersfield or anywhere else in the world needs to be done carefully and properly. The Kirklees Council (Kirklees Council, 2015) has promulgated jurisdiction which needs to be understood and followed for successful implementation. This literature reviews and evaluate two heating solutions: the Worcester Bosch Green Star 4000 Range gas boiler and The Earth Save Product Green Line 22kW heat pump system with buffer tank and water cylinder, according to the local regulatory frameworks and requirements, specifically focusing on their application within Huddersfield's regulatory environment. The essay also contains content from the HVAC codes and standards (Amara, 2016); Energy efficiency HVAC systems (Jouhara & Yang, 2018) and Updates on HVAC Regulations and Building Codes (Team, 2024)

2.5.1 Common regulatory requirements

2.5.1.1 Building regulations and planning permission

Under Kirklees Council's jurisdiction, building regulations approval is essential for HVAC installations and renovations in Huddersfield (Kirklees Council, 2015). The requirement for approved process which ensures compliance with safety and efficiency standards include:

- Planning Application Process, which contains the Submission of detailed plans; the Compliance with part L of building regulations for energy efficiency; Regular inspections during installation; Final approval from local authority building control officers (Committee on Climate Change, 2012); and additional requirements for properties in conservation areas.

- Properties in Huddersfield's conservation areas require more extensive additional planning controls while permitted development rights are more limited (Calderdale Council, 2006). Under the Planning (Listed Buildings and Conservation Areas) Act 1990, special considerations apply to buildings in these areas (Windsor, 2024). They are the Stricter controls on external alterations; Preservation of historical character; Specific guidelines for system placement; and the Enhanced planning permission requirements.

2.5.1.2 HMO licensing for student accommodation

- The Kirklees Council's heating, lighting, and ventilation regulations agree that adequate heating and ventilation systems must be paired with appropriate fire safety precautions and routine upkeep of common areas. Additionally, the provisions ought to be suitable and amenable.
- According to the Right management arrangements (Housing Rights, 2022), property managers are required to pass the "fit and proper person" test, keep up-to-date safety certificates, make sure that the property is inspected frequently, and take care of maintenance problems as soon as they arise.
- And additional licensing schemes may apply depending on the property's location within Kirklees.

2.5.1.3 Environmental and energy efficiency requirements

- Huddersfield's local environmental policies emphasize reducing emissions and improving energy efficiency (Gasperin et al., 2024) while integration of low-carbon technologies in new developments and renovations. They also appreciate the energy efficiency standards and sustainable development practices.

- The heating system requires meeting specific performance standards for space heating demand (Central Lincolnshire Authorities) including the minimum energy efficiency ratings; performance standards for space heating; hot water delivery requirements and carbon emission limits.

2.5.2 System-specific requirements

2.5.2.1 Worcester Bosch Green Star 4000 Range (Gas boiler)

- The system boasts 94% efficiency rating, with modern design with full-color text display, compatibility with intelligent filling systems and flexible installation options.
- Under Kirklees Council's regulations, gas boiler installation must be carried out by Gas Safe registered engineers. It is expected to satisfy specific energy efficiency standards while complying with local building control requirements (Committee on Climate Change, 2012). After the installation, it needs to undergo regular safety inspections.
- Installation in Huddersfield properties must follow Kirklees Council's building regulations, which are include appropriate ventilation systems; satisfy local environmental policy requirements; and consider conservation area restrictions if applicable (Windsor, 2024).

2.5.2.2 The Earth Save Product Green Line 22kW (Heat pump)

- The system's features include low GWP refrigerant (0.02) and high flow temperatures up to 75°C. It is rated A+++ in heating efficiency and has remote monitoring capabilities.
- Heat pump installations in Huddersfield must align with the local decarbonization goals (Gasperin et al., 2024), MCS certification requirements, Kirklees Council's environmental policies and Building regulations for renewable technologies.
- The specific requirements for Huddersfield installations include compliance with local planning permissions, satisfy the noise level restrictions in residential areas, integrate with existing heating systems and consider of conservation area guidelines if applicable (Calderdale Council, 2006).

2.5.3 Local Contractor Requirements

- Contractors working in Huddersfield must hold appropriate certifications for HVAC installations (Energy Star, 2025); comply with Kirklees Council's contractor requirements, include Gas Safe registration (for gas installations) and MCS certification (for heat pump installations); understand local building regulations and planning requirements (Kirklees Council, 2015); and ultimately maintain necessary insurance and qualifications.
- Contractors must demonstrate professional standards such as technical competence, knowledge of local regulations, health and safety compliance and proper insurance coverage.

2.5.4 Key differences between options

Table 3. HVAC option comparison

	Gas Boiler System	Heat Pump System
Planning and Approval Process	Established approval pathway under Kirklees Council Well-understood regulatory framework Simpler documentation requirements Regular inspection procedures.	Additional environmental assessments More complex planning requirements Detailed technical submissions Enhanced monitoring requirements
Installation Complexity	Straightforward installation process Familiar technology for contractors Existing infrastructure utilization Standard maintenance procedures	Complex system integration Buffer tank considerations Electrical system modifications Specialized maintenance requirements Align better with environmental goals (Gasperin et al., 2024)
Environmental Compliance	Meeting current efficiency standards Potential future regulatory challenges Carbon emission considerations Regular environmental assessments	Superior environmental performance Low GWP refrigerant Renewable energy alignment Future-proof technology
Cost Implications	Lower initial installation costs Established maintenance procedures Potential future carbon taxes Regular safety inspection costs	Higher upfront investment Potential government incentives Lower operating costs Complex maintenance requirements

CHAPTER 3
METHODOLOGY / PROJECT

3.1 House Overview.

Based on an in-depth interview with the landlord, the subject property—a mid-terraced house in Huddersfield—exhibits specific characteristics regarding dimensions, construction, and existing systems. This primary data provides a contextual foundation for the analysis of HVAC options and energy performance improvements.

The property was sold to the landlord in 2015 with the intention of leasing it to students. Hence, the house is expected to be fully occupied throughout the academic-year rental cycle or more. He applied for the large HMO license in 2023, which allows him to have a maximum tenant of 11 people. At the moment the occupation is 7 people.

Water usage is expected to be significant with the daily consumption of showers, sinks, toilets, and washing machines. The heating needs are also predicted to be huge as Huddersfield is reported to have long days of coldness.

18:04
Kirklees COUNCIL
House in Multiple Occupation (HMO) Licence
Housing Act 2004, Part 2

LICENCE NUMBER: LN/900000229

The Premises:

3 Smithy Lane Moldgreen Huddersfield

The Licence Holder:

[redacted]

Licence Duration:

The licence is valid until and including: 14/09/2027

Maximum Permitted Occupancy:

The licence is granted for **occupancy** of the premises by 2 or more households totalling **no more than 11 (Eleven) persons.**

The Manager:

[redacted]

The licence is granted subject to the conditions specified within the attached Schedule of Conditions.

Signed:
Name: [redacted]

Designation: Team Manager
Dated: 22/05/2023

A copy of this licence is to be displayed in a prominent position at the property at all times

Figure 8. HMO license

EE 15:05 60%

Back Your new energy...

Your tariff info.
(all prices include VAT)

Tariff name	Next Secure Fixed 12m v22
Starts from	12:00 AM, 1st Oct 2024
Electricity	
Unit rate	20.54p per kWh
Standing charge	68.32p per day
Gas	
Unit rate	5.51p per kWh
Standing charge	31.73p per day

Annual usage.

Electricity	7,942.8 kWh
Gas	37,285 kWh

Figure 9. Energy usage

The house has a total floor area of 175-meter square with 7 bedrooms, 3 bathrooms, 2 kitchens and 1 living room. Below are the floor plans:

Figure 10. Floor plan

The window system used in the house is the UPVC double glazing internal vent. They are on each floor, with at least 1 emergency exit window. Currently, the heating system used in the building is the gas heating system, combined with the Pro combi boiler 85 HE with the energy used is 25kW/h.

Figure 11. Boiler

Figure 12. Boiler pipe

This is a condensing boiler, provides hot water to the house which comes to the tap and the shower. Also, it provides heating to the house. This mechanism operates by gas. There is a gas pipe going into the boiler (1st pipe in the image) which contains gas that ignites when needed. In detail, when there is a demand for hot water, a signal will be sent to the boiler, in which the water will be heated up by the ignited gas. The heated water will go out in another pipe (2nd pipe in the image) to where the tap is. By applying this mechanism, instant hot water is provided anytime without an extra tank to keep pre-heated water or constantly heat it. Whenever someone turns the hot tap water on, there will be a green light appearing, signaling the boiler.

Figure 13. Boiler when working

For the heater, it is set vias the controls (in the image) which will come on when it is set to “on” and will be switched off when it is set to “off”. Using the same mechanism, the gas would ignite a different section of the boiler which is the ‘compressed water system’. The underlying cause of the difference is that the water for heating needs to be under pressure as it must stay inside a closed loop in the pipes under the radiator. This means the water cannot escape, instead it goes around the house. When the heating is on there is a pump which starts pumping the water around all the radiators. The water goes around then comes back through the other pipe before starting a new round again. Hence, the radiator stays hot all the time. The heat received from conduction – the hot metal – and convection – the air around.

When the gas is burnt, exhaust fumes which are carbon monoxide (CO) will be produced. The burnt gas is released through the balance flue, which is a solid metal pipe mounted directly on the wall to the outside.

Table 4. Ventilation, ductwork and extraction

	Bathroom	**Kitchen**	**Heating**
Ventilation	Mechanical fan extraction		
Layout	Straight out the wall through grill		Connect to the boiler
Ductwork	Plastic 100 mm diameter pipe	Silver 150 mm diameter pipe Has humid stat sensor	Solid metal pipe called balanced flue
Extraction	23 liter per second	550m3 per hour	

3.2 Insulation calculations and deployment plan.

3.2.1 Introduction

In order for any project regarding energy efficiency to be successful, it is essential to perform precise calculations of the areas and prices of insulation. This process begins with choosing appropriate types of materials. As a result of the fact that each section of a building—the attic, the walls, and the floor—experiences different kinds and degrees of heat transmission, it is crucial to decide on the proper insulation materials for each specific part of the building. Then, the calculation method used to determine the required insulation area and cost is proposed. After that, an overview of the deployment plan is made, which details the step-by-step procedure for putting the insulating enhancements into practice.

3.2.2 Material selection

For the ceiling/attic and the floor, the insulated material is Rockwool Cladding Roll

For the wall, the insulated material is Huntsman Building Solutions Closed-Cell Spray Foam Heatlok HFO Pro for the external wall and Knauf Insulation Earthwool 50mm Acoustic Roll for the internal wall

3.2.3 Calculation details

3.2.3.1 Area measurement

The insulation area contains 3 different sections, which are the attic, the wall and the floor.

The attic calculation:

The attic has been converted into the second floor for tenants, which its ceiling calculated by times the length and the width.

Equation: length x width = ceiling area

5.75 x 10.8 = 62.1 m2

The wall calculation:

The external wall area is calculated using the height, the length and the width of the house. To conduct the answer, the length and the width of each are taken from the floor plan. They are combined for the perimeter before times with the height. The height of the building is measured by the researcher.

Equation: (length + width) x 2 x height = external wall area

The internal wall area is calculated using the measurement of the internal wall and the height of the house. To conduct the answer, the length of the wall from each floor is added together then times with the height. The height of the building is measured by the researcher.

Equation: length x height = internal wall area

Table 5. The external and internal wall area

	internal	external		height	area		sum	
		length	width		length	width	internal	external
Basement	16.15	7.48	5.15	2.1	15.708	10.815	33.915	53.046
Ground floor	3.52	5.52	4.15	3.02	16.670	12.533	10.6304	58.4068
1st floor	15.62	6.6	10.8	2.7	17.82	29.16	42.174	93.96
2nd floor	13.65	5.75	10.8	2.86	16.445	30.888	39.039	94.666
Floor thickness		6.3375	7.725	0.9	5.70375	6.9525		12.65625
Total area				11.58			125.7584	300.0788

Detailed calculations and raw data can be found in the supplementary Excel file (see Appendix).

The floor calculation:

According to the EPC, the total floor area is 175 m2

3.2.3.2 Insulation price

The insulation price is calculated with the formular:

Total area/volume x layer x unit price = insulation price

For the ceiling, the insulation material is Rockwool Cladding Roll (100mm). The area is 62,2m2, and the thickness is 30cm, while the thickness of the insulation material is 100mm, it is recommended to double the thickness for a better fit. Assume the cost is £15 per m2. The insulation price is:

62,2 x 2 x 15 = 1 866 (Sterling pounds)

For the external wall, the insulation material is Huntsman Building Solution FOAM-LOK 2000-3G area is 300,08m2, and the cavity is 30mm.

Assuming that the cost of the closed-cell spray is £100 per m3. The insulation price is:

300,08 x 0,03 x 100 = 900,24 (Sterling pounds)

For the internal wall, the insulation material is Knauf Insulation Earthwool 50mm Acoustic Roll. The area is 125,76m2, and the cavity is 25mm, while the thickness of the insulation material is 50mm (Wickes, 2018), it is recommended to cut the thickness in half for a better fit. The cost is £92 per 16,2 m2 (Wickes, 2018). Hence the coverage area would be doubled. The insulation price is:

125.76 x 92/16.2 x 1/2 = 357,16 (Sterling pounds)

For the floor, the insulation material is Rockwool Cladding Roll (100mm). The area is 170 m2, and the thickness is 30cm, while the thickness of the insulation material is 100mm, it is recommended to triple the thickness for a better fit. Assume the cost is £15 per m2. The insulation price is:

170 x 3 x 15 = 7650 (Sterling pounds)

3.2.4 Deployment plan

Step 1: Home assessing

Before starting the insulation process, it is recommended to have an energy audit to locate air leaks and existing insulation gaps. A thermal camera or smoke pencil can be used to detect drafts or cold spots.

Step 2: Air sealing

Air sealing is an essential step in the process as the air leaks waste more energy than poor insulation. The places to look after for sealing are the gaps and cracks of windows/doors; attic hatches, vents, and recessed lights; plumbing and wiring penetrations; and walls/floors near electrical outlets.

Step 3: Ceiling/attic insulating

Insulating the ceiling/attic is considered the highest priority as heat naturally rises, making these areas the primary locations where most heat loss happens. In the winter, it is reported that uninsulated attics account for 25–35% of heat loss (Chole Fairfull, 2022). The impact on energy efficiency can be created immediately by insulating the area, preventing warm air from escaping. The material used in this space is the Rockwool Cladding Roll, making the R-value of approximately 8,2 m^2K/W or R-46,6 in imperial units.

Step 4: Wall insulating

Uninsulated walls can result in 30-35% heat loss (Elston, 2024). The house has cavity walls, which is a type of wall construction with an airspace between the outer and inner walls (Designing Buildings, 2015). The internal wall insulation material is earth wool, making the R-value of approximately 0.7 m^2K/W or R-4 in imperial units. The external wall insulation material is closed-cell expanding foam, making the R-value of approximately 8,4 m^2K/W or R-48 in imperial units.

Step 5: Floor insulating

Floor insulation prevents 10-15% heat loss (Curtis, 2023). The process is complicated as under the floorboard are electric wires and water pipes, which makes the rockwool harder to fit. The R-value is approximately R-0.7 in metric units or roughly R-4 in imperial units.

3.2.5 Expected result

3.2.5.1 Energy efficiency

After the insulation, it is expected that the property's energy efficiency upgrading from EPC rating 55D to 70C. This represents energy savings, meaning that the energy spent on the same task is now less than before. The researcher’s assumptions on performance improvements include gas consumption reduction, heat retention and temperature stability. The multiple layers of insulation will significantly reduce heat loss through the building envelope. Less temperature fluctuation throughout the property, reducing the need for constant heating adjustments.

Current Energy Usage

- Electricity: 7,942.8 kWh/year (20.54p per kWh)
- Gas: 37,285 kWh/year (5.51p per kWh)

Post-Insulation Estimates

- Electricity: 6,751 kWh/year (15% reduction)
- Gas: 27,964 kWh/year (25% reduction)

3.2.5.2 Environmental impact

The insulation process has significant benefits on the environment. It will reduce carbon emissions and result in lower energy consumption, hence reduce pollution. According to Stanford University (2024), “energy efficiency is often the least expensive and one of the most effective ways to meet demand for energy services while reducing energy consumption and the associated climate and environmental impacts”.

3.3 Buffer Tank sizing.

3.3.1 Buffer Tank sizing overview

Sizing buffer tank is an important process as it will determining the appropriate size of a buffer tank to ensure optimal performance in heating. It helps stabilize temperature fluctuations, reduce equipment cycling, and maintain steady flow rates.

The buffer tank used in this case study is the Earth Save Products (ESP) 200L Hot Water Buffer Tank.

System overview:

- Property: 170 m² mid-terraced house in Huddersfield
- Occupancy: 7 rooms for up to 11 students
- Water points: 3 sink taps, 2 kitchen taps (no shower)
- Heating system: The Earth Save Product Green Line 22kW with 7 radiators
- Average water content per radiator: 7 liters
- EPC rating: 70C

Current energy usage

- Electricity: 7,942.8 kWh/year (20.54p per kWh)
- Gas: 37,285 kWh/year (5.51p per kWh)

Post-insulation estimates

- Electricity: 6,751 kWh/year (15% reduction)
- Gas: 27,964 kWh/year (25% reduction)

3.3.2 Buffer Tank sizing calculation

The Required Buffer Tank Volume (L) is calculated by the equation:

Required System Capacity (L) - Total System Volume (L) = Tank Volume (L)

Assuming:

- 11 people will have high demand for water usage
- 7 radiators across 170m² suggests distributed heating load
- Pipework: ~ 25 liters

For heat pump systems, a common guideline is 10-20 liters per kW of heat pump capacity. With the 22kW heat pump, the minimum water volume required would be:

22kW × 20 liters/kW = 440 liters minimum system volume

Total radiator volume: 7 radiators × 7 liters = 49 liters

Total existing system volume: ~ 74 liters

Required Buffer Tank volume: 440 liters - 74 liters = 366 liters

3.3.3 Buffer Tank sizing choice.

Integrating 2 Earth Save Products (ESP) 200L Hot Water Buffer Tank is a suitable choice.

CHAPTER 4
RESULT & DISCUSSION

4.1 Weather trends and HVAC implications.

According to the UK Met Office, there has been an upward trend in temperature, specifically the 10 warmest years on record in the UK have all occurred since 2002. And like many other parts of the UK, the summer in Huddersfield is getting warmer over the year due to climate change and the global trend of rising temperatures (Rowlatt, 2024). To illustrate this trend, historical temperature data from the Bradford weather station, the closest station to Huddersfield, was collected and visualized. The data underscores the growing need to adapt residential HVAC systems to accommodate these changing climatic conditions.

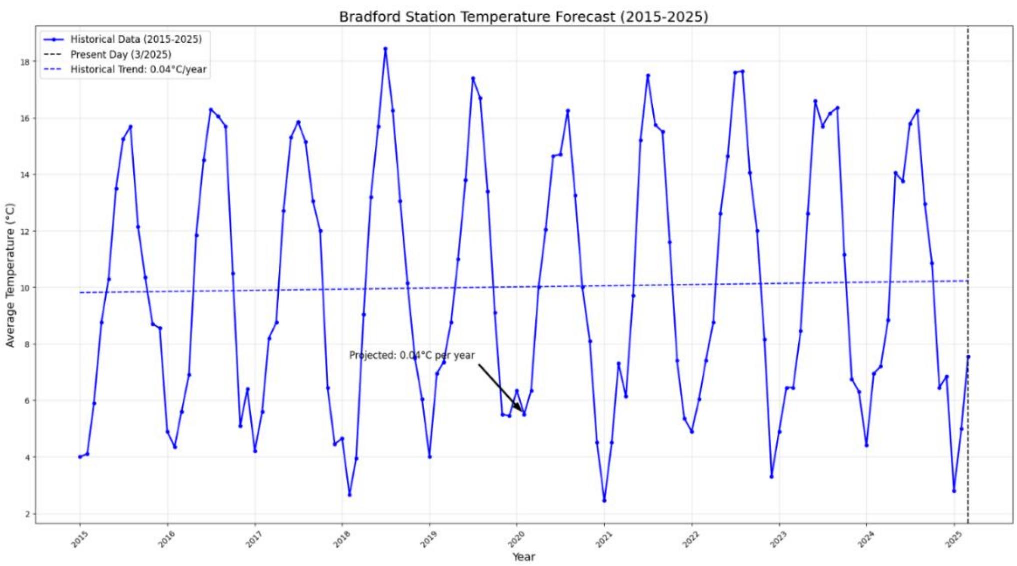

Figure 14. Bradford weather trend

For detailed information can be found in the supplementary file (see Appendix).

As the summer is getting warmer, so does the demand for Air Condition (AC). A survey has been conducted among current tenants of the property, showing that a majority of members have a preference for air conditioning during the summer months. This feedback highlights the necessity of considering cooling capabilities in the selection of HVAC systems for the property. Below is a chart summarizing the survey responses:

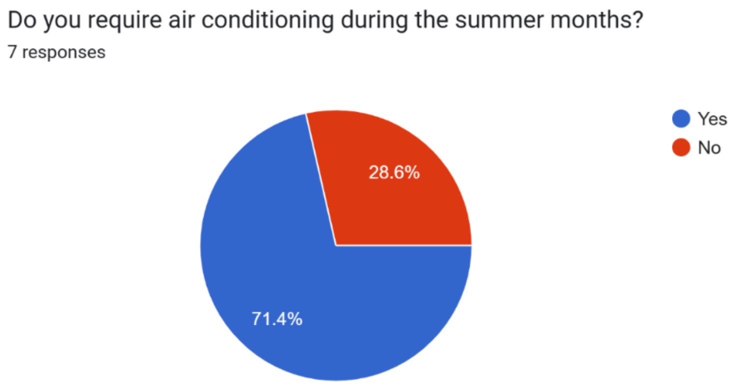

Figure 15. AC need assessment

When choosing systems to evaluate, the researcher has considered their compatibility with the property and their ability to address both heating and cooling needs. The Worcester Bosch Green Star 4000 Range (gas boiler) is more suitable for the house set up as the previous plan is also a gas boiler. It is compatible with all the existing radiators and provides reliable heating. However, The Earth Save Product Green Line 22kW paired with the Earth Save

Products (ESP) 200L Hot Water Buffer Tank offers a more sustainable and environmentally friendly solution, with the added benefit of addressing the increasing demand for cooling during warmer months.

However, as the trend suggested, installing a ductless mini system not only answers to the climate change issue but also to the Air Condition demand. A system with both heating and cooling capabilities is a viable solution. In the future where it is feasible to utilize the cooling feature, the landlord can remove the radiators and install the indoor unit, which is more convenient. This solution ensures the comfort of tenants throughout the whole year.

4.2 Life Cycle Cost on HVAC systems.

This assessment will discuss the Life Cycle Cost (LCC) in 10 years of the following systems:

1. The Worcester Bosch Green Star 4000 Range
2. The Earth Save Product Green Line 22kW paired with 2 The Earth Save Products (ESP) 200L

4.2.1 Energy usage and cost annually

Post-insulation energy usage estimates

- Electricity: 6,751 kWh/year (15% reduction)
- Gas: 27,964 kWh/year (25% reduction)

4.2.1.1 The Worcester Bosch Green Star 4000 Range

The boiler is a highly efficient condensing boiler. Assuming it improves gas efficiency by 10% compared to the Pro Combi Gas Boiler 85 HE.

- Gas usage:

  Gas usage after the insulation is reduced by 25% to 27964 kWh

  Gas efficiency improvement by 10%

  => Gas usage: 27 964 x (100 – 10) % = 25 167.6 kWh

- Electricity Usage: Remains the same as post-insulation: 6 751 kWh.

- Total cost:

  Gas cost: 25 167.6 x 0.0551 = £1 386.73

Electricity cost: 6 751 x 0.2054 = £1 386.85

Total Annual Cost: £1 386.73 + £1 386.85 = £2 773.58

4.2.1.2 The Earth Save Product Green Line 22kW with 200L Buffer Tank

Assume that the heat pump has a Coefficient of Performance (COP) of ~4, meaning it uses less electricity. Assuming heating accounts for ~60% of gas usage.

- Electricity energy for heating:

  Heating takes up 60% of gas usage:

  4 COP the electricity required for heating is

  => Electricity demand for heating: (27 964 x 0.60) / 4 = 4 194.60 kWh

- Electricity usage:

  Non-heating electricity: 6 751 kWh

  Heating electricity: 4 194.60 kWh

=> Total electricity usage: 6 751 + 4 194.60 = 10 945.6 kWh

- Gas usage:

  Non-heating takes up 40% of gas usage:

  => Gas usage: 27 964 x 0.40 = 11 185.6 kWh

- Total cost:

  Electricity cost: 10 945.6 x 0.2054 = £2 248.23

  Gas cost: 11 185.6 x 0.0551 = £616.87

Total Annual Cost: £2 248.23 + £616.87 = £2 865.10

Note: when integrating the system, the gas – based heat shower head will be replaced by the Agio Triton electric shower head, hence the Green Line will not be responsible for heating shower water.

4.2.2 Life Cycle Cost Assessment method.

4.2.2.1 Assumptions

- Inflation Rate: 3% per year
- Discount Rate: 5% per year
- Maintenance Costs: Annual servicing for boilers and heat pumps
- Disposal Costs: Included at the end of the 10-year period

4.2.2.2 Life Cycle Cost calculation

This calculation will address the following criteria:

- Construction cost (delivery cost, installation cost, material cost)
- Operation cost (material, energy & water cost)
- Maintenance cost
- Disposal cost

The C*onstruction cost* is calculated by the equation:

Delivery cost + Installation cost + Material cost = Construction cost

The O*peration cost* is calculated by the equation:

$$Annual\ Operating\ Cost\ \times \frac{(1+r)^n - 1}{r} = Operation\ Cost$$

r is the inflation rate.

n is the number of years in the asset's life.

The Maintenance *cost* is calculated by the equation:

$$Annual\ Maintenance\ Cost\ \times \frac{(1+r)^n - 1}{r} = Maintenance\ Cost$$

r is the inflation rate.

n is the number of years in the asset's life.

The *Disposal cost* is calculated by the equation:

$$\frac{Future\ Cost}{(1+r)^n} = Disposal\ Cost$$

r is the discount rate.

n is the number of years in the asset's life.

The Total Life Cycle *cost* is calculated by the equation:

Construction cost + Operation cost + Maintenance cost + Disposal cost

Table 6. Life Cycle Costing Assessment

	Pro Combi Gas Boiler 85 HE	**Worcester Bosch Greenstar 4000**	**The Earth Save Product Green Line 22kW**
Construction Cost	£1,600.00	£2,500.00	£7,258.00
Operation Cost	£30,000.00	£31,795.99	£32,845.16
Maintenance Cost	£800.00	£1,200.00	£2,000.00
Disposal Cost		£306.96	£920.87
Total Life Cycle Cost	£32,400.00	£35,802.94	£43,024.03

Detailed calculations can be found in the supplementary Excel file (see Appendix).

4.3 Discussion.

The Total Cyle Cost for Bosch Greenstar 4000 and The Earth Save Product Green Line 22kW is £35,802.94 and £43,024.03, consequently. The Bosch Greenstar 4000 has an advantage of lower initial cost, and the installation complexity can be avoided. However. in the future it will affect on environment as of the carbon emission. In contrast, The Earth Save Product Green Line 22kW costs greatly as it is a payment for 3 machines. Nonetheless, the system is designed to be eco-friendly, and can solve the problem of weather warming up in the future. Furthermore, as The Earth Save Product Green Line 22kW is the heat pump, therefore is likely to be eligible for the Boiler Scheme Upgrade programmed.

The criteria for the grant include:

- Is owned (or managed) by the applicant, with responsibility to carry out the upgrade.
- Currently uses an older fossil-fuel boiler that is due for replacement with a low-carbon, energy-efficient system.
- Meets specific building and installation criteria, including working with an MCS-certified installer and complying with local building codes and energy efficiency standards.
- Demonstrates that the planned upgrade will substantially reduce carbon emissions and improve overall energy performance.

If all the criteria are satisfied, the recipient can receive up to £7 500.00, which makes the price become significantly competitive.

Overall, this study evaluated multiple HVAC options for a mid-terraced house in Huddersfield using a comprehensive Life Cycle Cost (LCC) analysis. By analyzing the technical performance from insulation upgrades as well as by examining installation, operation, maintenance and disposal costs, research provided valuable insight into balancing cost-efficiency, energy efficiency and environmental impact. Overall, conclusions suggest that traditional gas-based systems can offer low initial costs, providing vital long-term economic and stability benefits with advanced facilities.

CHAPTER 5
CONCLUSION

This case study aims to establish a cost-effective, energy efficiency HVAC systems analysis that is suitable with the mid-terraced house in Huddersfield by integrating insulation upgrades and a complete Life Cycle Cost (LCC) analysis. The research confirmed that targeted improvements, such as suitable insulation reduce energy intake and enhance common indoor comfort in extreme weather situations. The comparative LCC analysis highlighted that while conventional gas systems offer lower upfront costs, alternatives with advanced features may deliver enhanced long-term economic and environmental benefits.

The findings underscore the significance of a comprehensive assessment that considers not only the upfront instantaneous set up and renovation fees but also the future operational financial savings, as well as being environmental mindful. The results indicate that improved thermal retention, in conjunction with a carefully chosen HVAC system, can potentially elevate the property's Energy Performance Certificate (EPC) rating and foster a more sustainable and resilient housing solution.

Despite these positive insights, the study is limited to a single property as well as there are uncertain assumptions in cost estimates and insulation performance. Future research should detect a wide range of construction types and include long-term monitoring to refine the LCC model, ensuring that the proposed recommendations remain strong under different circumstances.

Finally, this dissertation contributes to the deep understanding of HVAC system selection in terms of shares of severe weather and aging manufacturing. It provides a practical framework for property owners and decision-makers, which moves towards investment, long-term savings and an essential field to balance environmental impact, and moves towards permanent energy solutions, and comprehensive construction sector, permanent energy solutions.

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