#ENERGIZEWORCESTER

Investigating Perceptions and Interactions Regarding Energy Consumption in Student Properties

December 14, 2018

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WPI

WORCESTER
Bosch Group

Energize Worcester Phase II:

Investigating Perceptions and Interactions Regarding Energy Consumption in Student Properties

An Interactive Qualifying Project (IQP) Submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
In Partial Fulfillment of the Requirement for the Degree of Bachelor of Science

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December 14, 2018

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Abstract

Energize Worcester is a project sponsored by the University of Worcester and Worcester Bosch which aims to identify factors within student houses of multiple occupation (HMOs) that cause excessive energy consumption. The project's goal was to understand both student perceptions and routines regarding their heating usage, as well as identify landlord concerns for efficient product improvements in their properties. Through the use of surveys, a focus group and participant observation, an in-depth analysis of these topics was completed to create recommendations for the future of such projects. Lack of landlord motivation to upgrade student properties and students' disinterest in sustainable lifestyles were two prominent factors found throughout the project. A case was created for the implementation of a new generation of smart heating systems to allow students to have more control over their heat while increasing sustainability within the home.

Acknowledgments

The following research proposal could not have been completed without the help of multiple sources along the way. We, the Energize Worcester team, would like to first thank our advisor Professor James Hanlan of Worcester Polytechnic Institute. His understanding nature, helpful feedback and guidance allowed for the successful completion of this work. Secondly, we would like to thank our sponsor from the Worcester Bosch Group, Richard Forrester. His technical knowledge of boilers and smart thermostats provided guidance that ultimately helped to shape the end goals and objectives of this project.

We would also like to thank our sponsors from the University of Worcester. Katy Boom, the director of Sustainability at the University of Worcester, who provided advice and guidance on this project that paved the way for our eventual objective formulations. We would also like to thank the members of the University Accommodations team, both Judith Bick and Pauline Walford. Their combined efforts in aiding the landlord population study helped our team gather crucial information needed for the completion of this project.

Lastly, we would like to thank Professor Courtney Kurlanska from Worcester Polytechnic Institute. Her help in initiating our ideas and thoughts about this project, along with her helpful guidance and feedback on initial documents, helped build the groundwork for the overall research project. Without the help of all these people, the formulation of this paper would not have been possible.

Executive Summary

Introduction:

At the University of Worcester, Houses of Multiple Occupation (HMOs) are a concern due to their excess energy consumption. This type of house contributes to about 25% of the CO_2 in the United Kingdom (Hope & Booth, 2014). This issue stems from two main problems. First, student habits relating to their heating behaviors lead to energy over-usage. For most students, heat and other utilities are included with the rental agreement, creating an indifferent attitude towards wasteful energy usage. The second issue revolves around the architecture of HMO properties. Current properties are known for their thermally inefficient infrastructure that cannot be easily upgraded. Solid walls and the small space create difficulty for installing insulation (Dowson, 2012). This amplifies the amount of heat needed to keep the residences warm.

The main focus of this project was to better understand specific populations regarding energy usage and heating systems. For the student population, understanding their perceptions regarding their heating behaviors could help to explain the excessive energy consumption, and allow corrective measures to be taken. The landlord population provides a different point of view. Understanding the landlord perspective, along with their motivations in implementing energy efficient upgrades, allows a case to be made for the viability of a smarter heating system market.

Methodology:

To investigate the issues presented above, the following set of objectives was created:

1. Determining the potential motivation and incentives for landlords and letting agencies in retrofitting their properties with smarter heating systems;
2. Understanding the relationship between the routines of students and their heating usage;
3. Understanding the usage and perception of students towards smart heating systems in order to determine the features most useful to this population group;

To complete objective one, a combination of methods was used to get a larger amount of data. The first was the distribution of a survey. This was done through the use of both email and letters sent out to the landlords on the University Accommodations Team's database. The survey focused on details of the residences' heating system, the heating payment system, and perceptions and potential usefulness of smart thermostat systems. The second method was a focus group for landlords. This covered a very similar set of topics to the survey but allowed for much more depth of response, discussion between landlords, and topics to be brought up that weren't expected.

In order to understand how students' routines and behaviors affected their heating usage both a survey and participant observation were used. This general student population was targeted with a survey that addressed questions for both objectives two and three, with some questions addressing routines and others addressing the use of smart heating systems. This survey was administered in highly populated places on the university's campus through QR codes that could be filled out on a phone or other mobile device. The second method to address student routines was through participant observation. While conducting this study, the research team lived in a variety of student housing and were able to collect quantitative observational data on heating systems.

The final objective was to understand how students perceive smart heating systems. This was discovered through a set of questions included in the same student population survey used for objective two. By combining these two objectives into one method, a broader area of necessary data was acquired without targeting the same population multiple times. The questions investigated how smart heating systems could address the issues discovered from their responses to the student routines questions.

Findings:

After the data analysis period of the research project was completed, multiple different conclusions were drawn. These conclusions take into account all the data analyzed, along with past findings of other Energize Worcester studies, and are described in the statements below:

1. **There is a lack of student control over their heating systems combined with an indifferent attitude toward these systems.** Participants in the survey and participant observation stated a lack of care for their individual heating systems. However, their busy schedules along with the heating systems lack of specific controls compound upon the existing problem of increased energy consumption.
2. **A lack of communication was found between landlords, student tenants, and the University of Worcester.** A disconnect between each of these populations creates confusion and a lack of understanding of one another. The current system utilized by the University, known as StudentPad, is not being utilized to its potential compounding these communication issues.
3. **There is a growing interest to invest in new technology in order to gain more control over current heating systems.** The smart feature survey found an interest in smart heating features, like that of mobile control and weather compensation. This interest shows a market exists for smarter and more efficient improvements to be made to existing student HMO properties.

Conclusion and Recommendations:

Once the overall Energize Worcester project was completed, a set of recommendations were drafted based on the findings drawn from the analysis. These recommendations span multiple different audience groups, with the landlord and student populations being the most prominent. The recommendations allow for future iterations of the Energize Worcester project to advance the research being done, and to allow more diverse information to be collected on this matter. These recommendations are stated below as follows:

1. **EasyControl Implementation:** Encourage the next few iterations of the energize Worcester project to oversee the implementation and data collection of the new and improved smart thermostat system from the Worcester Bosch group. The data collected from the HMO properties can then be compared to that of the older Wave system data to see if improvements occurred due to the new multi-zonal heating capacities of the new systems.

2. **Further Investigation into Letting Agencies:** One aspect of the housing system that needs improvement is the understanding of letting agencies and their partnership with the University of Worcester. A future Energize Worcester project should delve into the communication process between these agencies and the University, and compare the data to that of private landlords.
3. **Implementation of a capped billing system:** The creation of a cap on the current all-inclusive heating bill will provide a monetary incentive for students to be more cautious of the energy they consume. Over-reliance on an exclusive approach is not recommended, as it might prove too difficult for students to accept this responsibility. With a capped-billing approach, a compromise in the arrangement is made where heat is only paid for by students with excessive usage. Specifics of the agreement can be investigated to determine the most effective level for a cap.
4. **Analyze the newest Wave system data:** The analysis of the newest Wave smart thermostat data would provide important information regarding student tenants and their heating behaviors. In addition, installing a data logger in homes without a smart thermostat could act as a control group. The comparison of this data to past information collected, along with the potential new EasyControl data, would provide an interesting comparison between the different systems and possibly a means to accurately judge their effectiveness.
5. **Create a Training Program and Technology Workshop:** Creating a training program and a technology workshop is a possible corrective path to undertake. Some predominant issues come from a lack of technological understanding among both of students and landlords about the possibilities and capabilities of the new systems that are only now becoming available, along with communication issues between students, landlords, and the University. Educating the population on smart heating technologies and instruction about effective of better ways to communicate may hold great potential for could greatly improving energy efficiency at the University.

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1 Introduction

In today's society, a trend towards more sustainable practices aides in the protection of the environment, and in turn promotes the reduction of waste and decreases emissions. This increased awareness of sustainability helps to expose wasteful practices and creates motivation for negative environmental issues to be remediated. A more sustainable future is necessary to help preserve the environment for future generations so that these generations are not threatened by a ruined ecosystem caused by the neglectful practices of the past. The smallest changes, like recycling more often or turning off a light that seems futile, however, are a step in the right direction to create awareness for the excess waste people create today.

Houses of Multiple Occupation (HMOs) are the main concern in terms of excess waste and high energy consumption in the United Kingdom (UK), as these usually older residences are naturally an uncomfortable temperature due to cold and drafty spaces. This issue cannot easily be solved as the old infrastructure is not equipped to accept modern upgraded insulation, due to a lack of free space in walls (Dowson, 2012). In turn, there is a spike in heating usage in order to counteract this. While countless rules and regulations have been created by the government, landlords, and other sustainability-conscious groups alike to address this issue, HMO properties still have the issue of excessive energy usage which needs to be addressed in order to ensure a cleaner future. Even with this extreme energy consumption, residents aren't motivated enough to adopt sustainable practices and remain unsatisfied with their home's comfort level. The unequal ratio of consumption to the satisfaction level is a common problem in the UK.

The University of Worcester has worked diligently with student tenants, landlords, and the Worcester City Council to find ways to reduce energy consumption and to specifically target students in off-campus HMOs. Methods, like controlling boiler usage and investigating tenant awareness of energy consumption, have been attempted, however, the problem remains. The combination of drafty spaces and high foot traffic due to varying student schedules make energy consumption abnormally high. Compounding upon this basic problem is the lack of knowledge among students about how much energy they are using. Often, they feel as though this consumption responsibility falls on the landlords and therefore are not attentive to the amount of energy they use. Due to competition in the housing market, landlords have been forced to include

heating in the base price of the rental agreement. By having a fixed price for heating, tenants do not have a significant incentive to decrease usage. Due to this complex issue, the University of Worcester determined to find a solution to this problem.

The University of Worcester partnered with the Worcester Bosch group in 2013 to establish Energize Worcester. The goal is to reduce student household energy bills and protect the environment through smarter energy usage. With newer Worcester Bosch boilers installed in a sample of homes, along with their custom Wave smart thermostat, data has been collected to help understand tenant energy usage. Between the information acquired from the boiler usage logging system as well as survey and interview results from previous IQPs on the opinions of students about their energy usage, a vast amount of information on this subject has been gathered. These smart systems aim to reduce the overall consumption level of each resident by allowing them to more closely control their heating system. Past projects have concluded that, despite the newly installed system, reduction in student energy consumption hasn't happened, and the system does not perform to initial expectations. These past project groups left recommendations for our group to further pursue and therefore did not dive deeply enough into the concept of the smart heating system to arrive at specific conclusions and recommendations.

This research phase intends to delve into the specifics of how students interact with their heating systems in order to determine how new generations of smart heating systems could be used effectively. Landlord perceptions are explored, allowing both sides of the problem to be addressed, and current barriers to be identified. Through the study of these two populations, a holistic view on the issues related to heating systems can be developed. This provides insight for creating a set of recommendations to move forward with the implementation of newer heating systems better suited to a student's lifestyle.

2 Background Chapter

This section aims to introduce the overall issue occurring in Worcester, UK, which involves the excess energy consumption of HMO residences. These types of housing still contribute to roughly a quarter of the total CO_2 emissions each year in the United Kingdom (Hope & Booth, 2014). The main issue can be linked to the old infrastructure and poor insulation of homes throughout England. This has created a long list of problems ranging from heating issues to health issues. For this project, our main goal and focus of research revolve around student perceptions and behaviors related to their heating systems at the University of Worcester. While the new Bosch thermostat and boiler systems are supposed to help reduce the usage of energy by increasing user control over heating, consumption levels continue to be abnormally high. With the help of our sponsor, Worcester Bosch, research will be conducted on these smart thermostat systems to understand the issues causing the systems to fail to meet expectations. The concept of sustainability and its adoption is then discussed, as the usage of the smart systems is put forth to address energy inefficiencies and aid people to reduce their consumption. An emphasis is also put on student off-campus homes, called HMOs, as these residences tend to have a high energy usage to heat level ratio. This literature review reflects our research into the functionality of the smart thermostat systems and explains our interaction with the University of Worcester and our sponsor, Worcester Bosch, that allows a full understanding of the topic.

2.1 Energy Consumption in the UK

There has been a recent push towards sustainability in housing in the United Kingdom. The housing in the UK is some of the least efficient in western Europe and makes up 28% of the UK's total carbon dioxide emissions each year (Hope & Booth, 2014). In order for the UK to meet their legally binding target of reducing carbon emissions by 80% by 2050, the low efficiency of space and water heating and electricity must be dramatically improved (Hope & Booth, 2014). While there has been an increase in housing stock in the last 40 years, carbon dioxide emissions from housing have decreased by more than 20% (Hope & Booth, 2014). However, this has not been a linear decrease and many factors such as harsh winters and fluctuating energy prices have influenced this pattern (Palmer & Cooper, 2013, p. 11). With

more widespread improved energy performance, the UK is making a conscious effort to change their ways, but the HMOs are not keeping up with this trend.

Figure 2.1: Energy Consumption for the Average Household for a British city. A map showing the highest and lowest average energy consumptions per household (McCormick, 2011)

The Standard Assessment Procedure (SAP) is the rating system used to measure the energy performance of houses (Hope & Booth, 2014). The SAP has an A-G rating and is the basis for an Energy Performance Certificate (EPC) which is needed when selling and renting properties. An A-C rating is the best energy rating for homes. Only 8% of privately rented homes have an A-C rating, which makes these types of homes the least efficient of all types of housing in the UK. Until 2008, landlords were not required to provide an EPC for their HMO properties (National HMO Network, n.d.). This further perpetuated poor energy efficiency, as landlords had no incentive to increase the SAP rating, and thus the energy efficiency, of their properties.

The inefficiency of heating is also affecting the tenant's ability to pay their heating bills. With increased energy costs and inefficient insulation or heating systems within homes, 19% of households in the UK are considered fuel poor (Hope & Booth, 2014). Fuel poverty is when a

tenant spends more than 10% of his/ her annual income on heating or energy costs. The fuel poverty rates have been rising significantly each year as a result of the poor energy efficiency within many homes, making them difficult and expensive to heat (Hope & Booth, 2014).

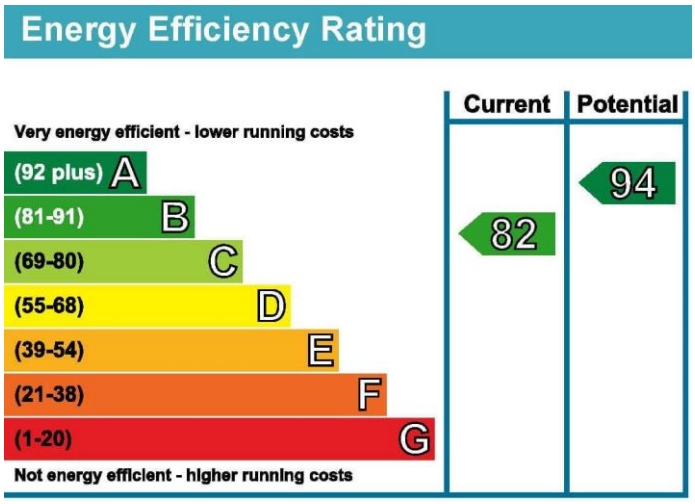

Figure 2.2: Energy Efficiency Rating.
An example of an EPC rating using the energy efficiency scale (Evergreen Energy, n.d.).

2.2 Worcester Bosch

Our sponsor for Energize Worcester: Phase II is Worcester Bosch, the leading boiler brand and manufacturer in the United Kingdom. Due to their popularity throughout the UK, they are a helpful resource in terms of their heating systems installed throughout Worcester. Worcester Bosch supplies heating products and systems, including boilers, heat pumps, control systems, and solar water heating. Their products are also designed to be energy efficient, which allows them to meet the goals set in their annual sustainability report. In this report, Worcester Bosch provides details as to how they are working at becoming a more sustainable company and provides data of the progress being made (Worcester Bosch Group, 2018b).

Worcester Bosch also pairs eco-friendly heating systems with smart thermostat products. Their specialty brand system, the Wave smart heating system, provides the user with more control over their use of heat. This system allows users to control the heat level in their flat more efficiently and allows them to set temperature points and program heating cycles. Due to the

sponsorship and their relation with the University of Worcester, these systems have been placed in five off-campus HMO residences at the University. The environment-friendly background of Worcester Bosch will help guide the Energize Worcester project in the right direction, especially in the area of the heating systems installed in the HMOs properties to allow a better understanding of heat and energy consumption of these properties.

2.3 Sustainability Efforts

This section provides information on how the United Kingdom as a whole is working on improving their carbon footprint. As described in the previous section, the United Kingdom is notorious for its inefficient energy consumption, as the old infrastructure makes it difficult for the implementation of more green buildings and the regulation of energy usage. However, recently sustainable living has been a top priority in England, and around the globe in general. Different policies in the United Kingdom have been introduced to increase sustainability and promote green living (Office for National Statistics, 2017). From the government enacting regulations to schools like the University of Worcester promoting a green and eco-friendly lifestyle, sustainability efforts allow projects like this to thrive throughout the United Kingdom.

2.3.1 Government Assistance

The Government has taken significant steps to make the United Kingdom a greener country and has created and established many rules and regulations over the past decade in order to achieve enhanced energy efficiency. Multiple goals have also been spelled out to allow for continual progress points to be reached and surpassed in upcoming years. In the following sections, examples of new developments in the area of sustainability will be discussed and explained.

The Clean Growth Strategy and The 25 Year Plan

The Clean Growth Strategy follows the simple idea of growing the national economy, while simultaneously reducing carbon and other greenhouse gas emissions. In October 2017, the government published this strategy that provided proposals for lowering emissions in the UK economy throughout the 2020s. The strategy follows a long line of successful attempts by the

government of creating a cleaner future. In 2008, the Climate Change Act was enacted by the UK to reduce gasoline emissions by 80% or more by 2050 (The Clean Growth Strategy, 2017). Even before this act was passed, the UK had managed to cut its emissions by 42% since 1990, making it one of the leading developed countries to reduce their carbon footprint. This strategy builds upon the past and current success of spreading sustainability across the UK and sets forth a plan to continue the reduction of emissions. Another significant contribution to the sustainability effort that the United Kingdom has provided is the 25 Year Plan, which is a comprehensive, 151-page proposal written and published on January 11, 2018. This plan is entitled *Our 25 Year Plan to Improve the Environment (The Plan)* and is a monumental step in terms of increased sustainability efforts, as this plan solidifies increased efforts over the course of upcoming years to reach projected goals. In creating guidelines like these for the future, the sentiment for a cleaner and more sustainable environment is solidified and shows that our efforts in Energize Worcester will not be in vain, but rather welcomed sincerely.

The Green Deal

The Green Deal was officially launched by the UK government in January of 2013 and allows homeowners to make energy-saving improvements to their residences without paying for all the costs upfront. The sustainable improvements implemented are paid for through the savings on respective energy bills (Proceedings of the ICE - Energy, 2013). By making the upgrades accessible to property owners, it will give more widespread access to energy efficiency improvements. This is one of the main ideas of the scheme, as more people ideally will implement the improvements if the cost is more reasonable. In terms of improvements, anything ranging from the installation of new heat pumps and boilers to wall insulation and solar panels is supported. For example, the company Worcester Bosch can install their Greensource air-to-air heat pump, which according to their website is up to 500% efficient, and the homeowner would not have to pay out of pocket for the device. After the installation, the energy bill will have a small charge each month for the improvement until the improvement fee is paid off. However, the 7-10% interest rate made has discouraged many from using the Green Deal Loan, resulting in a lower rate of improvement than initially hoped (National Audit Office, 2016). The Green Deal encourages landlords and tenants alike to think about the idea of improving their previous

existing heating systems and has helped place eco-friendly systems into some of the off-campus housing at the University of Worcester.

BEIS Energy Innovation Program

This clean energy initiative was first formed in the fall of 2015. In the same year, the UK government doubled its spending on clean energy research and innovation, with the intention to spend 400 million pounds a year by 2021 (Department for Business, Energy & Industrial Strategy, 2017). From this, the Energy Innovation Board created an innovation program, with aims to accelerate clean energy technology in the upcoming decades (Department for Business, Energy & Industrial Strategy, 2017). The clean energy technologies vary drastically. For example, the program supports smart meter systems like The Wave in households while also supporting nuclear power innovations (Department for Business, Energy & Industrial Strategy, 2017). The broad scope of the type of clean energy encouraged under the government's policies allows for as much innovation as possible in terms of producing cleaner energy. The program itself does not look into creating the technologies but instead funds multiple companies and research groups throughout England. This is important for Energize Worcester and Worcester Bosch, as the BEIS program will invest roughly €70 million into smart systems, and €90 million into the built environment. The built environment is considered to be energy efficient systems and improvements (Department for Business, Energy & Industrial Strategy, 2017). The additional funding for energy efficient systems will allow for greater progress to be made in the field of sustainability.

2.3.2 Sustainability at The University of Worcester

Colleges and Universities throughout the world are known to be centers of sustainable practices, as they both promote green activity and build clean energy systems. This project will focus on the University of Worcester, which has won numerous awards for being a sustainable campus (University of Worcester, n.d.a). The University of Worcester is a public research university in Worcester, UK, and is the only Higher Education Institution in Herefordshire and Worcestershire with a student population of about 11,000 students. According to the 2017

edition of the People and Planet University League, the University of Worcester ranks at number 4 out of 154 universities of the UK's greenest universities. This ranking is not surprising, as the community at this university consciously strives to make the university more sustainable (University of Worcester, n.d.a).

The University has three main campuses, St. John's Campus, City Campus, and the Severn Campus. All three campuses are within walking distance of each other, with the university promoting sustainable travel between them. Car sharing, bike loans, and discount bus tickets all promote more environmentally friendly means of transport than does the use of the private motorcar. Additionally, the Cycle to Work program offered at the university gives tax exemptions to all staff for buying bikes and bike safety equipment to help encourage biking to work as a healthier and more sustainable option (University of Worcester, n.d.a).

The University created a Sustainability Committee in 2005, with the head of the committee being the Sustainability Academic Lead. The committee is made up of a group of student representatives. They have a wide range of responsibilities on the campus including the creation of recommendations to executives at the University about aspects of sustainability and social awareness (University of Worcester, n.d.a). The committee also works with the surrounding community and other groups to help promote and facilitate green initiatives as well as publishing yearly reports on the progress that has been made. There are also many other sustainability programs at the University of Worcester, ranging from the Biodiversity Strategy to the Woo Bike share program. The University has a broad scope when it comes to creating a green future, which is why their programs are so diverse.

A big factor in the green development at the University of Worcester is the Environmental Management System (EMS). The EMS was created and given guidance by EcoCampus and aims to give framework and guidelines to control the environmental responsibility of the University. The system has been in place since 2007 and allowed the University to both minimize negative impacts on the environment and also promote and implement green projects. In 2010, the University of Worcester became the first university in England to receive the EcoCampus Platinum Award (University of Worcester, n.d.a). EcoCampus is a project originally funded by the Higher Education Funding Council in 2005, with the goal being to give guidance in designing and implementing an environmental system.

In terms of this research project, the University of Worcester has recently aided in the Energize Worcester: Phase II project, and has extensive plans in terms of reduction of energy usage. The University published an Energy Management Strategy from 2013-2018, which is the continuation of their previous installment. The main idea behind the strategy is to outline goals that promote sustainable practices, and methods to achieve these goals in upcoming years. For example, the University is aiming to reduce carbon emissions by 40 % by 2020 (University of Worcester, n.d.a). The Student Switch Off campaign is one of the many ways the university plans to reach this goal. The campaign provides incentives for students living on campus to lower their energy usage. In 2017 the university set a goal to reduce the use of gas and electricity consumption by 6% (University of Worcester, n.d.a).

2.4 Origins of Energize Worcester

Energize Worcester is an ongoing project that aims to reduce student household energy bills and protect the environment through smarter energy usage. It encourages students to think about their own energy efficiency when there is little incentive to do so. The Energize Worcester project is led by the Worcester Students' Union and works with Worcester Bosch Group, Worcester City Council, students, and landlords to move towards more sustainability in the HMOs. The project was first started in 2013 on the University of Worcester's campus and has since been backed by the National Landlords' Association and funded by the National Union of Students Green Fund (University of Worcester, 2014).

The University of Worcester and their student union received funding from the National Union of Students to launch Energize Worcester in 2013 (University of Worcester, n.d). The project has two phases, Phase I and Phase II currently. Phase I collected much-needed data of HMOs tenants and landlord's awareness of their energy usage and heating issues. Phase II utilizes this data and provides an analysis to find trends and root causes of the energy inefficiency in Worcester, UK. Previous WPI research projects have analyzed data collected and made recommendations as to how to increase sustainability. One example of a recommendation is to make the heating system multi-room accessible. Instead of one common dial to control the heat throughout the apartment, each room should be heated separately. This would allow for only certain areas to be utilized at a specific time of day, instead of the heat systems constantly

running. Other work revolves around The Wave, a smart meter system utilized by UK residents. The smart system has not worked as expected to reduce energy consumption, and efforts were made to understand why this is the case. Ample amounts of data from surveys and interviews of tenants and landlords are available from past research projects, and an in-depth analysis of the data will allow conclusions about the increased energy usage to be reached.

Figure 2.3: Past Worcester Polytechnic Institute students Chas Frick, Alex Shoop, Nick Lemere and Stefan Smith with University of Worcester director of environmental sustainability Katy Boom (middle), 2014

2.5 Student Housing Accommodations

The University of Worcester houses over 1,000 students in their on-campus housing. This leaves a large population of the students to live off campus. Most of the off-campus accommodations are HMOs. Housing is considered an HMO if there is more than one household that has a shared toilet, bathroom, and kitchen facilities (Gov.uk, n.d.). A household is considered to be members of the same family that live together. HMO properties require extra responsibilities for the landlord, including fire and general safety, water supply and drainage, safe gas and electricity, safe communal areas, adequate waste disposal and good living accommodations (Gov.uk, n.d.). If HMOs are three stories or more and are occupied by five or

more people, then there is extra licensing that is required for the landlord (Citizens Advice, n.d.). The University of Worcester has an Accommodation Team that helps students find off-campus housing in HMOs near the campus. The Accommodation Team also works with the Worcester City Council as well as landlords to ensure that the students living off campus have housing that follows regulations (Citizens Advice, n.d.). They also offer legal advice on the housing such as tenancy agreements and safety and fire codes of the HMOs (University of Worcester, n.d.b).

The University of Worcester also provides their students with an online document for how to find, manage, and negotiate through living in an off-campus apartment. The document lays out plans for the students to prepare to move in for their successive years. Additionally, the document goes over how to negotiate contracts with the landlords, what to expect in terms of financial and personal responsibilities, and who is responsible for keeping things in working order.

2.5.1 Incentives Related to Supply and Demand

Currently, throughout the UK, housing demand in the private housing sector, including HMO properties, is low (Ambrose, 2015). A weak housing market, in turn, creates lower rental prices and ultimately less profit for landlords. This forces landlords to create incentives for potential tenants in order to make their housing more enticing. One common incentive is including the energy bill in the rental agreement as a set fee regardless of the energy being used. This type of billing is very appealing to students for two reasons. The first is that this aspect of living is predictable and therefore easier to plan and budget. Since many of the tenants looking at this type of housing are students, not used to living alone, they are not fully aware of the bills associated with their previous heating habits. The second is that student tenants do not need to worry about their energy habits. This leads to wasteful behaviors such as leaving the heat on while away, or keeping the heat at higher setpoints. Coupled with the inefficiency of the homes, this type of lifestyle can lead to high energy usage as well as massive amounts of energy loss.

2.6 The Tenant and Landlord Gap

Among the other problems that hold back the energy efficiency for these homes, motivation to change these norms is among them. The difficulty with motivation comes from the

disconnect between the tenants' and landlords' views about the energy use in the household. The two most common situations for the energy dynamic in households go as follow: 1) The landlord provides a set fee to the tenants for heat/electricity that is included in their rent, and 2) The landlord charges the tenant proportionally for the amount of energy that they use throughout that specific rental period.

The first situation is one that normally leads the tenant to be less energy-conscious since there is no financial incentive to conserve. According to one study, tenants who have their utilities included in their rent would set their thermostats 1 to 3 degrees warmer in the winter months while away, given all other conditions were the same (Levinson, 2004). This is a small relative difference in energy use, but on the absolute scale, this leads to quite a large increase in energy. In the UK, domestic energy use accounts for 28 % of the total energy used (Department of Business, Energy & Industrial Strategy, 2017). Of that 28 %, 68 % of the energy used by the domestic sector is in the form of natural gas (Cuce, 2016). Since this type of energy can really only be used for heating purposes (be it heating water, heating the house, cooking, etc.), it becomes apparent that even a small increase in energy use, by comparison, becomes quite a large amount of heating in the end. Despite these potential extra costs to the landlord and extra use of energy, landlords still use this type of billing scheme. This is because there are some benefits to having a set price on the heating. The first main benefit is that having a consistent bill for tenants is much more competitively attractive, and thus draws in business for the landlord. The second is that it motivates the landlords to adopt more energy efficient measures to drive down necessary energy use (Levinson, 2004). Because of these benefits, this method of billing is still used.

The second situation described is one that encourages the tenants to conserve energy whenever possible. By being held accountable financially for the energy that they are using, the tenants become the ones that are trying to save energy. As mentioned before, even small relative energy reductions in the household lead to a large total energy reduction. However, there is a bit of a problem with this method of billing. By having the tenants be responsible for the energy use, they are more inclined to make requests for energy saving technologies to the landlords for approval. Unfortunately, the landlords have no incentive to act on these requests and can prevent the overall efficiency of housing from increasing. This is a problem because European households have a very long lifespan, and thus can become very outdated in terms of efficiency

(Astmarsson, 2013). Since the landlord has no reason to improve the household, energy use can still be a problem even if the tenants are living in suboptimal conditions to save energy.

In both situations, the driving force for energy overuse stems from the differences in the tenants' and landlords' perspectives. Both methods of billing lead to one side having to carry the burden of finding ways to save energy. Meanwhile, the other side seems to either completely ignore the problem or make it worse. Dealing with this disconnect could make significant strides towards finding an energy efficient solution that both sides can agree on.

2.6.1 Letting Agencies Vs. Private Landlords

A more unique aspect to the city of Worcester is the number of private landlords renting out HMO properties to students. These landlords do not work for a larger company and have bought and managed properties with extra income they have acquired. This is unlike other cities in the UK where larger entities as a whole rent out properties to prospective tenants. In turn, they can control a larger portfolio of properties and hold a greater influence in the community. These larger entities are known as letting agencies, and while slightly less prevalent in the city of Worcester, still make up a large part of the rental market. Both types of rental agents work closely with the University of Worcester to help find suitable off-campus housing for students. Due to the differing viewpoints between individual landlords and letting agencies, each provides strengths and weaknesses in terms of their student rental schemes.

Private landlords have been thriving throughout the UK as more and more people acquire properties for economic income rather than housing (Ronald & Kadi, 2018). This is due to the growing connotation that the housing market is a reliable income investment. Because of this, the University of Worcester works increasingly with these landlords to help find students proper off-campus housing. The main service used by the University of Worcester to contact these landlords in known as Student Pad, and helps connect landlords with both students seeking homes for rent, and the Accommodation Team that overlooks this process. Since these landlords are not affiliated with a larger corporation, they have less standardized rules and regulations between them. Yet, each individual still has to meet requirements set by both the Worcester City Council and the university itself (Information for Landlords, 2016). Due to the personalized aspect of these private landlords, more personable communication can occur between the

landlords and tenants, along with faster response times to housing issues. However, the University has noticed a lack of communication from these landlords, and also a lack of incentive to improve their rental property. Since this means of revenue is not their primary source of income, less attention to the properties and upkeep is given. Enticing these types of renters, especially when it comes to costly improvements, then becomes an issue that the University of Worcester has been trying to manage.

Letting agencies provide a different aspect to the rental scheme for the University of Worcester. Due to their larger entity and manpower, more properties can be managed in their portfolio without affecting customer service at each property. From this, more communication happens between the university and these agencies to allow a smoother experience for students keen on off-campus housing. The main agencies that the University of Worcester work with are the Platinum, Premier, Parallel and Black Pear agencies. Most of these agencies are well-established companies that the University has worked with for a while and trust in aiding students in their search. Black Pear, on the other hand, is a newer agency that is still learning the methods to provide student accommodation and service. Unfortunately, these agencies are not just intended for student housing, which impacts their attention to detail regarding students and their needs for housing.

Figure 2.4: An example of an HMO student accommodation.
This setting is provided on the Black Pearl Letting Agency website (Black Pear Lettings, n.d.)

2.7 Implementation of Smart Thermostat Systems

Technology has been improving at a rapid pace for many years, with more and more devices gaining smart capabilities and becoming connected to the outside world. Internet of things (IoT) devices have expanded to almost every product in the home, with everything from speakers to thermostats to lightbulbs becoming internet enabled. All these devices come with lofty goals of improving quality of life and increasing efficiency, yet adoption has been slow. Many devices' capabilities are over-promised and simply not refined enough for the average user to want in their lives. They also open up the doors to possible security risks if safeguards are not implemented properly.

One of the most popular smart devices is the smart thermostat (Herrero, Nicholls & Strengers, 2018). A smarter thermostat seems to have significant benefits, such as more advanced timers and the ability to control setpoints remotely from a phone. These systems also have some built-in logging and data processing to help show the user their usage habits, as well as some possible ways to save energy. One of these systems is the Worcester Bosch Wave thermostat. Using data collected with this system that was installed in certain HMOs, this project

aims to better characterize and identify habits of student energy usage in regards to using these Wave systems.

Adoption of smart thermostat systems will increase in the coming years due to new legislation enacted in April 2018. This legislation mandates that all new heating systems must have some form of smart features (Gov.uk. ,2017, p. 9). This legislation requires that all new systems have, at a minimum, a timer-based system for adjusting setpoints. For combination boilers (heat and hot water in one system), which are very popular in the UK, one of the following features is required (Gov.uk. ,2017, p. 10).

- **Flue gas heat recovery systems:** Heat pump to recover some of the waste heat from the exhaust gas
- **Weather Compensation:** Change setpoint depending on the weather to more quickly react to changes (system will become hotter when it's colder outside).
- **Load Compensation:** The system will increase the water temperature if the residence is significantly below the setpoint then adjust once normalized.
- **Smart controls with automation and optimization functions:** A link to a phone or computer to allow for wireless control and adjustments with minimal user interaction.

2.7.1 Current Implementation of the Wave

Worcester Bosch has developed a proprietary smart thermostat system to be used with their line of boilers. The system can be controlled through either the wall-mounted touch panel or a phone app. The system can be linked to up to 8 different devices at a time that then gains control over settings (Worcester Bosch Group, 2018b). One useful feature of the Wave is the ability to log information about the system. This data can be used to try to find trends among the heating methods utilized by the tenants. The Wave has a variety of different smart modes that are aimed at increasing user comfort while decreasing energy consumption. The exact implementation of features is somewhat unclear as most information comes from vague marketing materials. Some of those features are as follows.

- **Home presence detection:** By checking for the connection status of any devices on the system's network the number of people home can be estimated. This information can be used to adjust settings accordingly.
- **Weather compensation:** Outside temperature for the location of the home is used to adjust the indoor setpoint temperature.
- **Energy history graphs:** Graphs to show how much energy has been used in the past year or month.
- **Holiday mode:** Lower setpoints during times in which the homes will be unoccupied and raise them back before the vacation is over.

Figure 2.5: The Wave smart thermostat system control panel and app display (Worcester Bosch Group, 2018.b)

There are some notable downsides to this system, especially as related to an HMO. The Wave only supports one heating zone. In addition to this, if there are multiple devices connected to one system then the one with the highest setpoint will take priority. Both of these downfalls are especially important for student housing. When there are many occupants in one residence who have varying heat preferences, zones are crucial to avoid heating everywhere in the flat even when only one resident is home. In addition, the fact that the highest setpoint takes priority means that the heat can really be set higher than most residents want.

2.7.2 Future Implementation of the EasyControl System

Building on the work put into the Wave system Worcester Bosch released an updated smart thermostat in May 2018 called the EasyControl. This system improves upon the Wave in almost every way, refining the features of the previous system while also adding in a new set of features (Worcester Bosch Group, 2018ba). Some of the key new features are the wider compatibility of boilers to which the system can be retrofitted, including more older models, as well as the ability to set different zones each with their own set point. Where the Wave system requires a Worcester Bosch boiler to work, the EasyControl can work with other brands which use the openTherm standard. The electronic thermostatic radiator valves (eTRVs) of the system can be easily retrofitted onto standard thermostatic radiator valve (TRV) from the previous non-smart system (Smart radiator thermostat EasyControl, 2017). This system is made up of a control panel and a set of wireless thermostats that mount onto each radiator, allowing more fine control from room to room. These wireless thermostats can then be set up in the system's app to link each one to individual rooms and allow for the multi-zonal control (Worcester Bosch Group, 2018ba).

Figure 2.6: The EasyControl eTRVs and application.
The EasyControl system with 3 eTRVs (PlumbNation, n.d.).

This functionality of a multi-zone setup addresses the greatest pitfall of the Wave system for an HMO setting. The features that carry over are also more refined which may increase the adoption due to the learning curve being shallower and results more pronounced. The system is also still under development with new features such as virtual assistant (Amazon Alexa)

integration planned to be added in the future (Worcester Bosch Group, 2018ba). Adoption of this system is expected to increase due to a richer feature set and legislation requiring some form of smart features in new installations. To see if this system actually has a noticeable improvement in consumption versus the Wave, Worcester Bosch could install this system in another subset of HMOs and compare the results to see if the improvements have an effect on the user experience.

Figure 2.7: The EasyControl application.
The User Interface of the EasyControl System on a smartphone (Apple Inc., n.d.)

2.7.3 Consumer Opinions on Smart Home Systems

Smart heating systems have been promoted as having the ability to improve the quality of life and decrease energy usage compared to a normal thermostat. They have the ability to do this by being easier to interact with and responding to their environment, both by interacting with outside sources and learning the user's habits. While adoption has been increasing, a vast majority of homeowners haven't found the need to upgrade. This can be significantly attributed to the fact that the technology doesn't have a broad enough feature set to offset the cost and inconvenience of setting up and learning the system (Herrero, 2018).

Since their conception, these smart home devices have over-promised in terms of heating sustainability. When early versions were released in the 1990s, claims of 20-30% energy savings were publicized (Herrero, 2018, 67). So far, the devices have far from lived up to these expectations. Without an immediately noticeable effect, users are less likely to put in the effort to set up and learn to use some kind of smart device. In one study, a smart device was used which

utilized a smart plug and could control any device that was connected to this plug. Only a quarter of participants ended up using it for the whole trial time. One quarter didn't even attempt to set it up, another 25% attempted but gave up without success, and the last quarter got it set up but quickly stopped using it (Herrero, 2018, 67).

Studies have shown that, without significant incentives, users are reluctant to use a system that seems complicated. Ease of use is one of the most significant factors facing the adoption of smart home systems (Rubens, 2013). Currently, these systems are best suited to a specific group of individuals: people with a consistent routine that can be programmed into a smart home system are more likely to save energy and actually utilize the smart features. Those who are more proactive, many of whom are motivated by the cost savings, are much more likely to put in the time to learn and consistently program the system (Rubens, 2013). Until the barrier of entry becomes even lower and the potential for savings increases, the adoption of these systems will remain slow.

2.7.4 Security Concerns of Smart Systems

As homes become continually more connected to the outside world the issue of privacy remains a major concern. More standard devices in the home are having internet connected versions released. These internet of things (IoT) devices offer a variety of convenience features to the user, but almost all of them rely on collecting some form of data. This data is required to get the functionality out of the system but becomes an issue if it falls into the wrong hands and someone gains access who shouldn't. Some examples of possible nefarious uses are burglars determining if the home is unoccupied, companies using data to form target advertising, and police using home presence detection as an alibi (Mckenna, E, 2012, 808). Many of these are protected under regulations, but that still leaves the opportunity for outside organizations to gain forced access.

A major regulation that came in to effect earlier in 2018 that affected anyone who stores user data was the General Data Protection Regulation (GDPR). This tightens the rules on anyone that stores personal data, requiring the company to justify why they have the data and allows any user to make a request to reveal what is stored about them, which must be fulfilled in one month or the company could be subject to a fine. This also placed major restrictions on the use of

personal data for target advertising (Information Commissioner's Office, 2018). Worcester Bosch has attempted to avoid these concerns as much as possible by not recording any data on their servers but instead keeps all logs local. For the homes that are participating in a research study, an external system is required to send the data to a Bosch server, and those homes have consented to participate in the study.

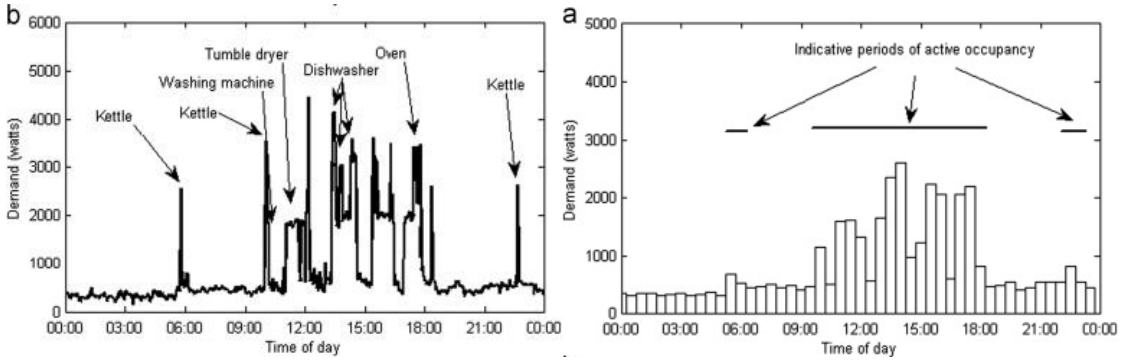

Figure 2.8: An example of smart meter data and an interpretation (Mckenna, 2012).

2.8 Background Conclusion

The issues of aging housing infrastructure and high energy usage impact all of England. The climate and aging housing infrastructure pair together to create the highest consumption of fossil fuels for heating in Europe. Organizations like the University of Worcester and Worcester Bosch are attempting to find a solution to this issue through projects such as Energize Worcester. This problem has negative effects on both the environment and an individual's health. This research project will focus on these issues in student housing and attempt to find areas for improvement to living conditions and energy consumption. To find these improvements, the relationship between tenants and their respective smart thermostat systems will be explored, with the goal of finding tenant opinions of the system and their perceptions of what features would be most useful for a student. The use of the actual heating system will be investigated through the Worcester Bosch Wave thermostat system in an attempt to discover the habits of the users that lead to an increase in consumption. The intersection of students and their heating system will also be explored to determine how student tenants interact with their technology and how the heating system can best help the individual.

3 Methodology

To completely understand the task at hand, a set of research objectives was formulated to understand student behaviors and beliefs relating to heating principles within their residences. Each of these objectives is a goal that was set in order to collect and analyze any necessary data. These objectives were then used to fulfill the overall project goal of understanding the ways in which students utilize their heating systems. These objectives included:

1. Determining the potential motivation and incentives for landlords and letting agencies in retrofitting their properties with smarter heating systems;
2. Understanding the relationship between the routines of students and their heating usage;
3. Understanding the usage and perception of students towards smart heating systems in order to determine the features most useful to this population group;

Each objective stated involved different aspects of student-heating behaviors. The goal of each objective required extensive exploration into different aspects of student residential energy consumption, with a greater focus on smart thermostat systems and consumer interaction with these devices. To identify the problems associated with heating usage, a variety of methods were used to gather data. Using a combination of new data and past research, an analysis was conducted that formulated recommendations. The implementation of these recommendations will ideally result in reduced energy consumption by student-tenants.

Since this project focused on the perceptions and behaviors towards heating usage, multiple populations consisting of the general student body, student landlords and letting agencies were studied. The main concern in studying these groups was obtaining a significant number of responses in order to maximize the amount of information collected. This required designing method tools that were simple and quick for the target groups to complete, and therefore encouraged more participation in the data collection. With more data collected, viewpoints were more accurately mapped, as well as the similarities and differences between perceived behaviors among groups.

3.1 Objective 1: Landlord and Letting Agency Motivations

The ability for student tenants to be more energy conscious relies heavily on the thermal efficiency of the property and the efficiency of heating systems utilized in their homes. The task at hand was to understand the motivation, or lack thereof, of landlords towards retrofitting their properties with smarter heating systems that could potentially improve the thermal efficiency of the homes. Since individual landlords and letting agencies determine whether these improvements will be implemented, an understanding of their sentiment about eco-friendly systems being installed was valuable information regarding the relationship between homeowners and the amount of energy efficiency that can be achieved. In order to accomplish this, combinations of surveys, interviews, and focus groups were used for data collection. Additionally, the research team presented its work at the annual Worcester City Council Landlords Forum to gain more exposure within the community about the project.

3.1.1 Preliminary Landlord Survey

There are a substantial number of landlords throughout the city of Worcester. However, a focus was placed on only student landlords of the University of Worcester. To get in contact with these landlords, the Accommodation Team at the University of Worcester served as a liaison between the landlords and the research team. The Accommodation Team works closely with the landlords who house students and therefore was a helpful source in this correspondence process. They were able to email a short survey to the landlords on the research team's behalf. The survey contained 17 questions regarding their properties and heating systems. A paper version of the survey was also mailed out to the landlords through the postal system. An addressed return envelope was included with the survey to allow for ease of completion. The reason for the two different methods of survey distribution was due to the understanding that some landlords would prefer to use the postal system rather than that of an online system. This level of redundancy was utilized in order to increase the survey response rate.

3.1.2 Landlord Survey Analysis

Before the analysis of these surveys could be accomplished, all of the responses had to be organized in one location. For consistency, the responses received from the paper version of the survey were entered into the online tool. Once all of the responses were gathered, the data was exported from Bristol online surveys to an Excel file. This was chosen as a spreadsheet is a common format that can be easily imported into a variety of statistical analysis packages and which can present data in an easily understood graphics format.

The main program used by the research team was Matlab, as many of the researchers had prior knowledge of this programming environment. Matlab has an integrated statistical toolbox that offers a wide range of statistical methods and can easily import and export data as an Excel spreadsheet. Depending on the specific questions being compared, a different form of analysis was used. For questions that use a Likert scale or other parameters that could be translated to a numeric value, a Spearman correlation test was run. The Spearman correlation test was chosen as it compares ordinal data, such as a Likert scale, and does not rely on an assumption of a normal distribution. This determined if the variables being compared actually had a statistical significance. The other main statistical method used was a combination of simple and multiple regressions. These methods were used to determine if the change in one, or multiple, question responses correlates with a change in the chosen outcome response.

The results of these analyses were then visualized into charts to more easily convey the data. While the analysis was being done, Matlab's built-in plotting functions were used to quickly view results in real time. Once the analysis was complete, finalized plots were created using a combination of Matlab and Google Sheets. The Google Sheets environment was chosen for its configurable plots and ability to collaborate with all members of the team. The post-processed data from Matlab was exported into Google Sheets where the data was plotted using a standard format.

3.1.3 Post-survey Focus Group Conduction

The preliminary surveys allowed for a basic understanding of the student HMO landlord population and were followed up with a focus group of a select few landlords. The landlords selected for the discussion were those who promptly responded to the follow-up query. At the

end of the survey, each landlord was asked if they would be willing to take part in a focus group regarding similar topics. As recommended by the Accommodations Team at the University of Worcester, the focus group was held in the afternoon as this was most convenient for the largest group of landlords. The date of November 19th was then chosen for the group discussion, as this provided ample time for the landlords to prepare. The goal was to gather six to eight landlords which would provide the best group dynamic for a conversation to be held. The length of the discussion was less strictly set, however a length of an hour was expected. To entice landlords to attend the focus group and aid in the research study, tea and biscuits were provided and supplied by the University of Worcester. A quiet, spacious and private location on the Riverside Campus was chosen for the focus group to provide a comfortable and safe space for landlords to voice their opinions. During the focus group, the main conversations held were between the landlords themselves. However, two moderators were used to keep the discussions more focused and change topics when needed. Lastly, two note takers were utilized to transcribe the conversations held, along with a recording software from a smartphone to make sure all the conversations were saved for further analysis. Every participant was made aware of the recording and agreed to its usage, knowing the raw recording wouldn't be published. All these features on the format of this discussion were necessary to predetermine in order for the discussion to progress fluently, along with maximizing the amount of qualitative data collected.

Both the setup and formation of a focus group are crucial for successful qualitative data collection (Gill, Stewart, Treasure, & Chadwick, 2008). The idea of a semi-structured question format was used for the discussion, as this allowed differing ideas and topics to be presented (Lune, H., & Berg, B. L., 2012). These off-topic conversations within the focus group provided new material for the research team to consider and gave differing viewpoints on each of the topics due to the shifting nature of the multi-person discussion. The focus group provided a deeper and more in-depth understanding of the motivations of landlords to make improvements to their properties. Due to the social aspect of the focus group, a more comprehensive understanding of overall beliefs and views of student HMO heating surfaced, as each landlord could either build upon or dispute the various viewpoints expressed. This allowed a clear understanding of the cumulative landlord beliefs to surface regarding their motivations for energy efficient improvements to their student tenant properties.

3.1.4 Letting Agency Interviews

In addition to holding a focus group with the landlords, the letting agencies in charge of student housing were also contacted. The plan was to reach out to two different letting agencies in Worcester. First, Platinum Properties was chosen as it was described by the Accommodations Team as a well established letting agency in the community. They work with both student and non-student tenants. The second agency was Black Pear Lettings and was chosen due to its reputation as an up-and-coming agency that exclusively works with student tenants. The conduction of interviews would have allowed the collection of a wider range of information regarding the two letting agencies for the University of Worcester. Since these letting agencies are known for their professionalism in regard to their rental properties, these interviews provided a different viewpoint on motivations for eco-friendly improvements contrasted to that of the individual landlords (Berg, 2012).

The use of semi-structured interviews was utilized in the question guidelines, as any information gathered about the attitudes of letting agencies further improved the knowledge about their perceptions. (Lune, H., & Berg, B. L., 2012). Off-topic conversations within these interviews allow topics and viewpoints not previously considered to emerge and provided new material for the research team to consider. The semi-structured interviews addressed certain questions and topics that were previously agreed upon and deemed important to examine. However, when the conversations diverged from the pre-set questions, the new direction was embraced which allowed new topics and ideas to be presented. The goal was to interview each letting agency as a whole, with each individual interview lasting roughly a half hour. In collecting information through these interviews, more in-depth data of the letting agencies' perceptions, along with their requirements from the new systems, would have been gathered

Due to a lack of response in visiting these agencies, an email was sent out to 16 different letting agencies in the Worcester area. This email comprised of a description of the Energize Worcester project, and a formal question as to whether they would be interested in a follow-up interview. The email intended to branch out to more letting agencies in order to increase the response rate from the population. Both means of contact were used in conjunction in order to

gain more interest in the interview process, however did not garner the expected outcome. The lack of response is discussed in the upcoming results in section 4.4.

3.1.5 Interview and Focus Group Analysis

Since a large amount of data was collected through both the interviews and focus group, a few different approaches for data analysis were employed. For both the interviews and focus group, substantial amounts of transcription notes were taken during the discussion. For the focus group, the recording of the conversation was re-listened to multiple times in order to transcribe any missing information. From these, multiple pages of notes were created for both method types. Due to the quantity of data, two different qualitative analysis methods were used.

The first approach used was conventional analysis. This is a form of analysis that involves reading through the notes and transcripts made and creates categories for the different themes mentioned (Hsieh, 2005). A type of category, for example, used from the responses was 'responsibility', which entailed responses that were concerned with the student tenants and their treatment of their living accommodation. From these categories, the responses were then coded to create thematic elements that correspond to certain categories. To help create a standardized coding process within the research group, a codebook was generated in order to allow for a more meaningful and unbiased analysis. The codebook (see Figure 4.8) had many different iterations due to the acquisition of more knowledge after the discussions were completed and allowed more precise codes for certain topics (DeCuir-Gunby, Marshall, & McCulloch, 2010). Once themes and keywords were grouped, labeled and highlighted, a frequency count was initiated on the field notes assembled. The number of times the thematic variable was mentioned in the transcribed notes was multiplied by the ranking each category was given. The rank system gave each category a score, which was based on the categories relevance to the research study, and the importance it holds in the landlord's perspectives. The rank score was then multiplied by the frequency to receive a weighted score, which allowed a comparison to be made between each category established.

The next qualitative method used was directed analysis. This type of analysis compares past data and understanding of the topic at hand (Hsieh, 2005). From the coding and organization of the data accomplished by the previous analysis method, a comparison of results from previous

research groups with the newly acquired data regarding landlord views on heating usage was conducted. This comparison can provide either a clear confirmation or change in the previous perception of landlord views. Memo-ing was also utilized in the data exploration process, where notes on past understandings were used to find similarities throughout our new data (Hsieh, 2005). The memo-ing process involved taking a note on the page of certain responses to keep track of topics and keywords. A comparison was then more readily distinguishable between past and current data due to the memos and provided invaluable data that could either support or question previous understanding. This analysis process allowed the research team to clearly define landlord motivation for heating principles and allowed the team to conclude that a viable market exists for energy efficient heating systems in HMO properties. A deeper understanding of letting agency and landlord motivations allowed for recommendations to be made to Worcester Bosch about improvements or changes to the systems that would entice these renters to make property improvements.

3.2 Objective 2: Mapping Student Routine to Heating Usage

The main problem that plagues heating student HMO properties is the high traffic created from having multiple occupants. With many students residing in a single residence, their multiple conflicting schedules and persistent foot traffic create issues when it comes to heating. To understand these various schedules and how students handle the sporadic traffic in their flat, two separate methods were utilized. These were surveys and participant observation, which used in conjunction allowed the acquisition of more data. Surveys allowed more statistically driven data to be gathered, while participant observation allowed for a more qualitative understanding of the student heating dynamic due to the immersive experience within this environment.

3.2.1 Student Population Survey

The first attempt to research this objective of routines was to create a short survey. The general student population at the University of Worcester was surveyed in order for a larger and more diverse sample to be collected (University of Wisconsin, 2010). All of these students have to balance their academic schedule along with their domestic chores, which made their input

important and valid. The target population was students only, as this specific population's views are required to suggest improvements on future smart heating systems.

A quick online survey made up of 30 questions was used. These questions consisted almost exclusively of multiple-choice questions in order to make the survey manageable to complete on a tablet or other mobile device. Due to this distribution method, open-ended questions were avoided, with the one exception being if "Other" was selected as an answer to a multiple choice question. When "Other" was selected, an open-ended option was given to complete the question. Through trial runs of the survey before full deployment, most participants were able to finish within 10 minutes.

These surveys were distributed electronically to make them easier and faster to complete. This also helps to avoid errors from manually entering data from a paper survey. Distribution was done around the University of Worcester using a combination of tablets and QR codes. This was done so students could either fill out the survey on their phone using the QR code or on a provided tablet, whichever they found easier. The research team split into two groups and stood in busy spots on the University of Worcester's campus to ask students about smart heating technology in their student residences.

These questions provided a better understanding of foot traffic within student accommodations and provided comparisons between the schedules of students and how that affects their heating behaviors. Some questions asked on the survey used the concept of the Likert scale and utilized a certain scale to provide a sufficient range of opinions on the topic. In collecting the survey, the goal was to achieve a 20% response rate of the population. The population of on-campus students at the University of Worcester is 1,600 students. Ideally, with a 20% response rate in mind, this would result in a sample of 320 surveys. However, with the limited time period to distribute surveys at the University of Worcester, and past IQP population sample sizes taken into account, the realistic aim for a population size was 100 students. This was a much more realistic population target that could be attained in the allowed time frame.

3.2.2 Student Survey Analysis

The student survey was administered exclusively online due to the target demographic which removed any need to manually enter data. Just as was done for the landlord survey, all responses were downloaded from Bristol online surveys to an Excel file. The file was then loaded into Matlab and the same statistical methods as discussed in the previous survey analysis section were run on these survey questions.

Some of the data that was used for comparison was to determine if a student's age and gender would affect their likelihood to adjust the thermostat, and for what reasons a student would do so. The specific schedule related questions were also compared to see the normal amount of time outside of the home and if this was consistent between housemates.

3.2.3 Personalized Participant Observation

The next method of participant observation allowed the acquisition of qualitative data from both the students who were observed and from personal observations of heating systems used by the research group. Participant observation is a time commitment that requires a developed acquaintance with both the location and the people within the location of research. This process required a researcher to become familiar with the lifestyle of students at the University of Worcester, which created a clear understanding of daily actions and routines. This Energize Worcester team was spread across multiple campuses with the members occupying various different accommodations. This provided an intriguing opportunity to note personal use of heating systems in regard to a daily schedule. The intimate involvement provided invaluable information as to the ways students utilize their heating system as a result of their sporadic schedule. However, this technique required increasingly involved stages of intimacy between each researcher and the society under study. These levels of involvement go in order from the stranger stage, to the acquaintance stage, to finally the intimate stage (Munck and Sobo, 1998, p. 41-42). Each member of the team was placed directly into the student life, as all were placed in residences along with University of Worcester students. The first step was to become acquainted with the students, and eventually, team members became apart of their daily lives. This allowed each member of the team to thoroughly understand their respective flatmate’s daily schedules, and observe how they utilize their heat to stay warm during the increasingly cold weather. Due to

the somewhat invasive nature of this method, each tenant understood the observations that occurred and consented to participate in the research study. Once past the stranger stage, the acquaintance stage and intimate stage that followed allowed considerably more field notes that were more focused on the topic of student heating with respect to their schedules, and the personal heating methods of the researchers as well (Munck and Sobo, 1998).

3.2.4 Participant Observation Field Notes

To collect data for this method, an extensive amount of field notes were taken over the duration of the stay at the University of Worcester. In the beginning stages of this project, fewer field notes were taken due to the heating systems not being used regularly during warmer weather conditions, and also due to the initial unfamiliarity with the environment. As the colder season progressed, and the team became more acquainted with the student lifestyle, field notes started to be recorded on laptops of each team member. These notes consisted of the personal experience this team found in regard to regulating the heat, and also how their flatmates interacted with the heating systems. These notes were taken purely from user observation and contained notes specifically about how students regulated the heat. A few examples of these notes are students leaving their windows open to decrease heat and let in fresh air, and at what temperature setpoint the radiator was set to in order to keep a comfortable climate. The relationship growth over the course of the project allowed specific conversations to be held that gave a more in-depth understanding of daily schedules and heating usage. These conversations were not specifically about these topics but were spread out over multiple interactions with the students that allowed a more general idea of student-heating interactions. Again, the consent of the students to these conversations was essential, and it was made clear from the beginning that each student response would be kept anonymous. The integration of these conversations, along with the substantial field notes taken, allowed the research group to obtain a substantial amount of information regarding specific student interaction with their heating system and how this is affected by a demanding schedule.

3.2.4.1 Analysis of Field Notes

Once a substantial amount of data was collected through field notes and personal experience and observation, a compilation of all the data into one larger document began. This document consisted of field notes from each team member and was organized by time, date, and location. Once this compilation was completed, a coding process will begin to sort the extensive data. A similar coding process from the previous objective took place, as the same style of codebook was utilized to group topics and keywords. From coding the notes, certain trends in thematic topics and ideas surfaced and allowed the team to highlight important topic trends in the notes. The use of a standardized codebook (see Figure 4.29) made it easier to analyze the notes taken and was easily compared to previous data collected in past projects. A similar approach to that of the focus group analysis was used here (see Figure 4.8), where a weighted score was determined to easily compare the different thematic variables relevance within the raw data acquired. This comparison also allowed for either a justification or disapproval of previous claims made about student heating methods.

3.3 Objective 3: Smart Thermostat Expectations

As it currently stands, students have a complex set of beliefs to smart heating systems. Past IQPs have studied student attitudes towards smart heating technologies (more specifically Worcester Bosch's Wave) and there have been mixed feelings about them. While students have good intentions of using a smart thermostat to improve their home's energy efficiency, the follow through is often not there (White, et.al, 2018, p. iv). There are a number of factors that affect this lack of follow through on use of the smart thermostats. Many of these systems were not designed for houses with multiple tenants and lack key features like being able to split the home into different heating zones (Worcester Bosch Group, 2018). The technology has also been unintuitive and difficult to learn, causing students to have little incentive to fully use the system (Herrero, S et al., 2018).

3.3.1 Combined Survey Technique

In order to better understand how student tenants could benefit more from their heating systems, surveys were used. The first few steps of creating the survey were to have a goal in mind that the team was trying to achieve, as well as a target population intended to achieve that goal (Office of Quality Improvement, 2010, p. 5). The goal of this survey was to determine how smart heating systems can be better tailored to user needs. For convenience, topics and questions within the same survey regarding both student routines and student smart heating expectations were combined into one survey for both this objective and objective 3. Since this was a singular survey that satisfied two objectives, distribution efforts could be better focused on the student population to improve response rate. This survey provided a base knowledge for what students look for in a heating system and the level of effort they are willing to put in to improve their energy consumption. Through these surveys, information that further investigated whether smart heating technology could be more closely tailored to the needs of student tenants was gathered. By asking opinions about specific features of the current systems, recommendations for future systems can be tailored to the specifics that best fit students.

3.3.2 Student Survey Analysis

The data analysis for this section was done in parallel with that of the second objective since they are based on the same survey. The number of responses received for this survey was much greater than the one given to landlords, so correlations between different subpopulations (i.e. heat payment agreements or thermostat setups) were investigated.

A variety of specific relationships were looked at to determine potential correlation. The heating payment agreement was compared to the student perceived comfort and response to the temperature being too warm (i.e. opening windows). This aimed to show if the students who had to pay for their own heat were more energy conscious than those who had the bill included with rent. Another comparison was between the answers to the smart heating features section of the landlord and student survey. Both groups were given almost identical questions, so a comparison was made to see if both groups had a similar preference. A variety of other combinations of parameters were analyzed to see which had a strong statistical correlation.

3.4 Methodology Conclusion

To accomplish all of these objectives, a variety of methods were used in conjunction. There are a few major populations that were specifically targeted. The first group was the general student body living in some form of housing at the University of Worcester. This broad population provided greater understandings of student interaction with heating systems and student perceptions towards smart heating systems and features. The next group studied was the landlords and letting agencies for off-campus student HMO housing. The two groups were contrasted to see if one was more receptive to these modern heating systems. Through the use of these different methods, a case for the implementation of a new generation of multi-zonal heating systems in student HMO type properties was made.

4 Results

In this section, the results of each method tool are displayed to allow for an easy understanding of the data collected. Visuals and graphics of the results help portray the frequency and correlations within the data. One method of the data collection process was the survey given to the general student population at the University of Worcester regarding heating behaviors and attitudes. The results of the survey were compared with the participant observation notes to acquire qualitative data on student heating interaction in terms of their demanding school schedule. Our second target population in the data collection process was landlords of student HMO accommodations. Multiple types of distribution strategies for survey tools were used in conjunction to discover landlord attitudes towards implementing smarter heating systems. Additionally, the attitudes and behaviors recorded in a landlord focus group were coded to visualize the frequencies of various topics and motifs within the focus group. Letting agencies were also contacted through the means of interviews and an email survey. Unfortunately, this element could not be integrated into the data analysis due to a lack of response. The method tools of the surveys, participant observation and a focus group allowed for substantial data to be collected across the two populations researched.

4.1 Landlord Motivations for HMO Properties

The main results discussed in this section came from the surveys distributed to student landlords, along with the observations and discussions from the student landlord focus group. An electronic version of the survey was emailed to the landlords and a paper survey was also sent by post to help increase response rates. The response yield concluded with with 19 total responses by the 4th of December. The initial population size was thought to be 366, however, due to numerous errors in the list of landlords, the actual population size ended up being about 350 landlords. An exact size could not be determined due to the unknown sending errors. On top of the two different surveys distributed, a focus group was also held to collect data from the landlords directly. This provided more insight into unforeseen topics that the landlords discussed amongst themselves. A total of 3 landlords attended the focus group which lasted for 60 minutes. The entirety of the focus group was recorded and also transcribed (See Appendix E).

4.1.1 Results from Landlord Surveys

The use of two different delivery systems increased the response rate from the landlords, as responses came in faster once both were eventually distributed. A total of 19 landlords responded to the survey, with 13 responding to the email survey and 6 responding to the letter survey. From the sample size acquired, a general idea was determined amongst landlords about their perceptions and motivations in regards to heating in HMO properties.

Property Data

The first section of the landlord surveys focused on individual properties that the landlords owned specifically for student tenants. From the surveys collected, most landlords have an average of two student specific HMO properties. Regarding the sample size of 19 responses, a descriptive statistical analysis was performed and is shown in the table below. The table below takes into account all 19 responses from the landlords and displays fundamental statistics to better explain the distribution created. The most important piece of information is that the mean number of houses owned by student landlords is two HMO properties, with a distribution of +- 3.33.

Number of Student Properties Owned	
Mean	2.56
Median	1.5
Mode	1
Std. Dev.	3.33
Range	14
Minimum	0
Maximum	14
Count	19

Figure 4.1: Descriptive statistics of the number of landlord properties

The next aspect of the survey targeted individual landlord properties, as each respondent was asked specific questions about up to 3 of their most recently acquired student HMO properties. On average, the total number of students living in a single HMO property was 4 students.

With the responses of each of the HMO property questions combined, the sample size was 29 responses. There was a minimum of two students per house and a maximum of six students per house. This tight grouping explains the small standard deviation of +- 1.12 student tenants per HMO.

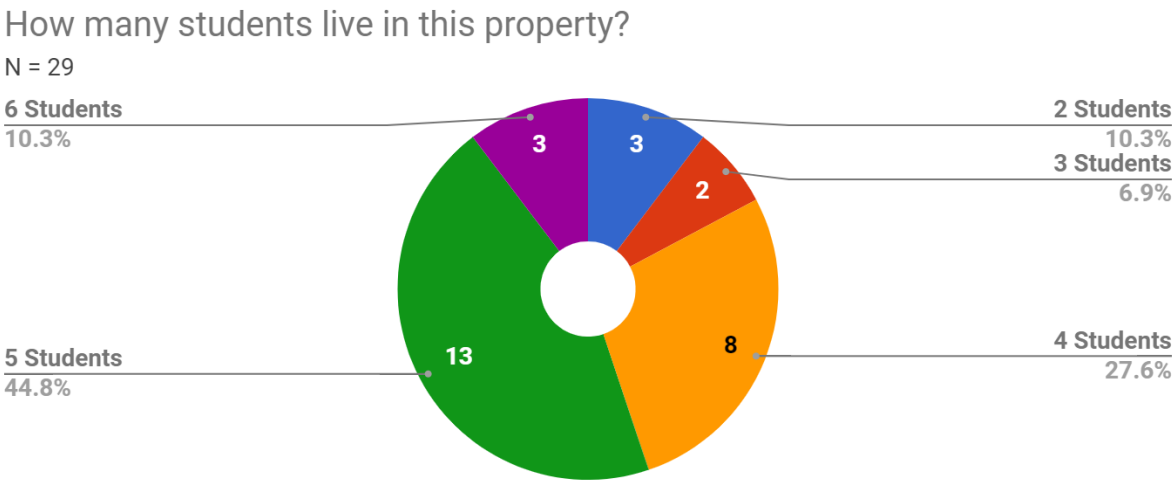

Figure 4.2: Depiction of the number of students per HMO property.

To determine the average age of the boilers in the properties, age ranges were specified and given rank values. For example, the 0 to 4 age range was given a rank value of 1, while the 5-10 age range was given a value of 2 and so forth. There were 33 data points collected, as some landlords have more than 1 student HMO property. From this sample size, the greatest rank value chosen was associated with the 5-10-year-old age range, with a count of 18. The second largest rank value was associated with the 0-4-year age range, with a count of 9. The lowest count for an age range was the 11-20-year-old age range, with a count of 2.

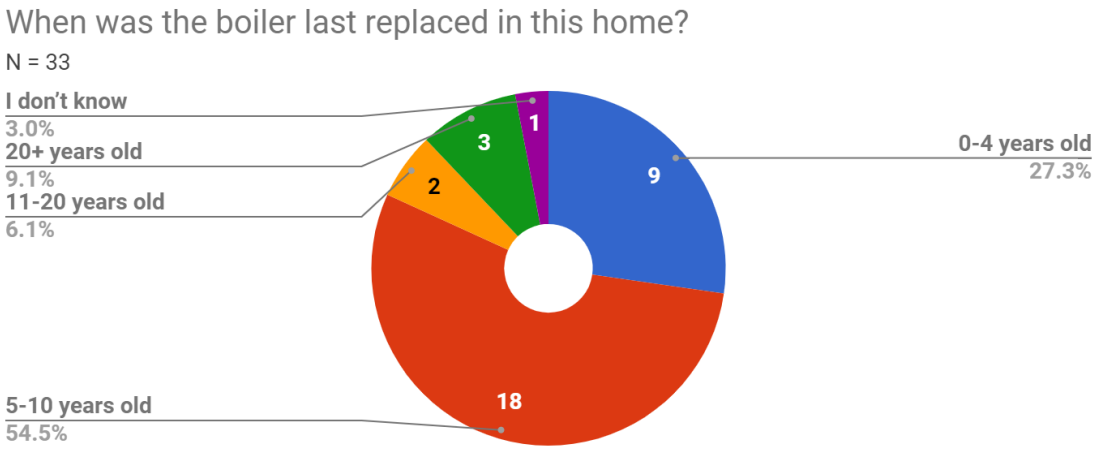

Figure 4.3: Age ranges of the boilers in the student HMO properties.

A question of whether these properties have a form of smart thermostat controls was then asked with a simple yes or no question style. Out of 30 responses, the majority of the homes do not have this feature, with a count of 24 out of 30 selecting 'No' as their answer. This results in smart thermostats within student HMO properties being present in 20% of the landlord properties, leaving 80% of the homes not having a smart thermostat. A distribution can now be made between the age-range of boiler systems to smart thermostat systems installed and is discussed later in the analysis section.

As for the payment methods, the number of homes with inclusive heating costs is 17, the amount of homes with a capped inclusive heating cost is 9, and the amount of homes with an exclusive heating cost is 5. This puts the sample size for this question at 31 responses and shows that inclusive heating is the most common type of billing as it occurs in 55% of student housing accommodations. A depiction of this is shown in the graph below:

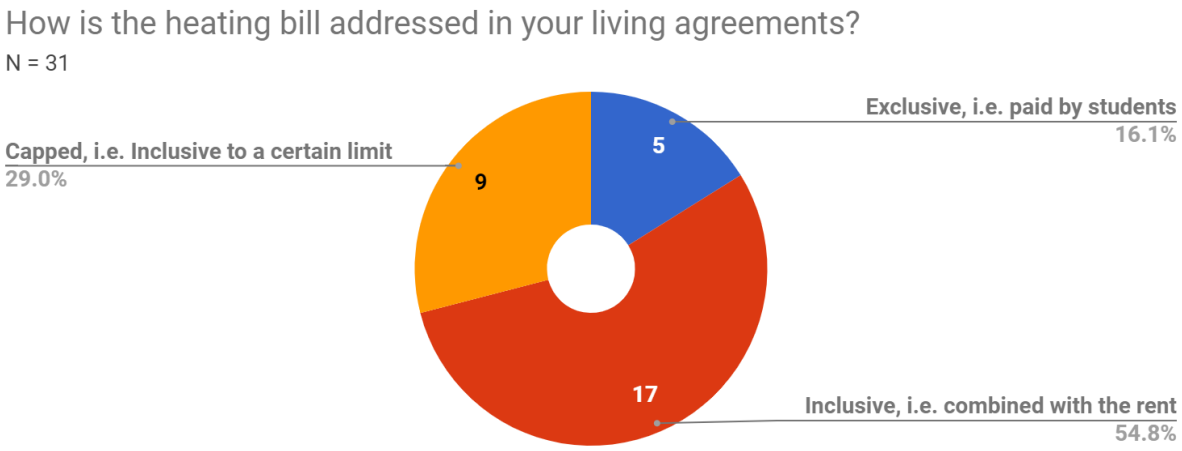

Figure 4.4: Choice of payment system for heat in student HMO properties.

Regardless of the type of billing system chosen, the most selected answer as to why a landlord chooses their billing system was to keep students happy. This answer received a count of 13 out of a sample of 32 responses. This places student happiness as the main reason for the type of billing system at a 41% occurrence among landlords. The second most selected reason was to keep the heating usage in check, which occurred 22% of the time. To ensure the pipes do not freeze was only chosen 3 times, giving it a 9% occurrence among the landlords surveyed.

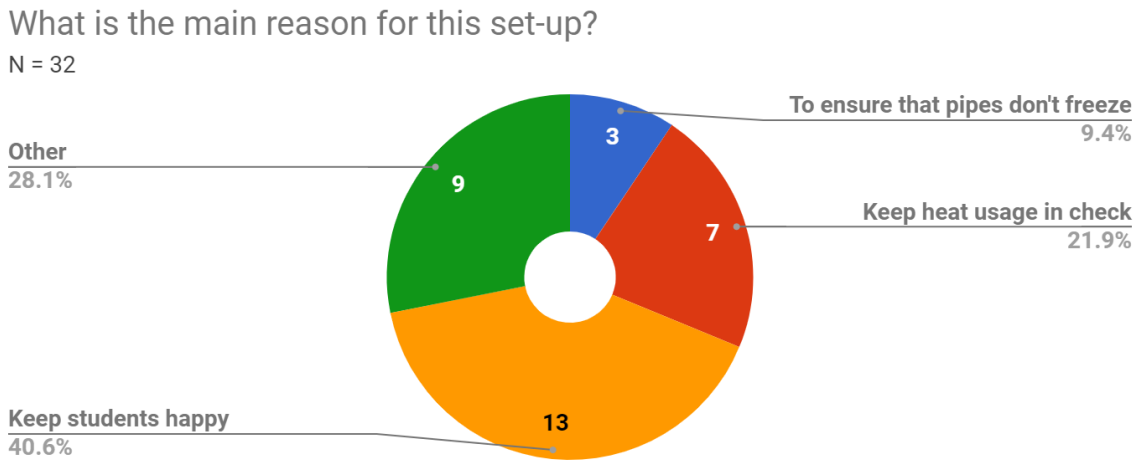

Figure 4.5: Depiction of why landlords chose a specific billing system for heat.

The other 28% of respondents selected ‘Other’ and explained why they chose their current set-up. Many of the respondents explained that the University of Worcester has set up a contract for the heating bill on the HMO property and that they do not have a say in how the system is implemented. Another response explained that the boiler has a timer and is pre-scheduled to go on and off at certain times throughout the day, leading to their decision in the previous question.

Student Tenant Data

The next section of the surveys focused on the student tenants that the landlords housed, and how the tenants behave according to the landlords. When asked about how often the student tenants inquired about temperature improvements in their houses, 0 responded with ‘Frequently’, 1 responded with ‘Occasionally’, 1 responded with ‘Very Seldom’, and 11 responded with ‘Never’. This puts the rank value of ‘Never or almost never’ occurring 72% of the time. Both ‘Yes, occasionally’ and ‘Very seldom’ occurred 14% of the time. The option of ‘Yes, frequently’ occurred 0% of the time, as this option received 0 selections.

As for the number of landlords who gave instruction on how to use heating, there was more variation in these responses. With a sample size of 18, the most common answer of whether landlords gave instructions to the students was that they did in some form, which occurred 78% of the time. This puts landlords not giving the students instructions occurring at 22% of the time. However, out of only the ‘Yes’ responses, which is a sample of 14, the most common answer was that the students listened to the instructions, and was selected 6 times. Both the students not listening and no knowledge of the impact were chosen equally at 4 times each. No landlord selected that they do not remember if they gave the students instructions.

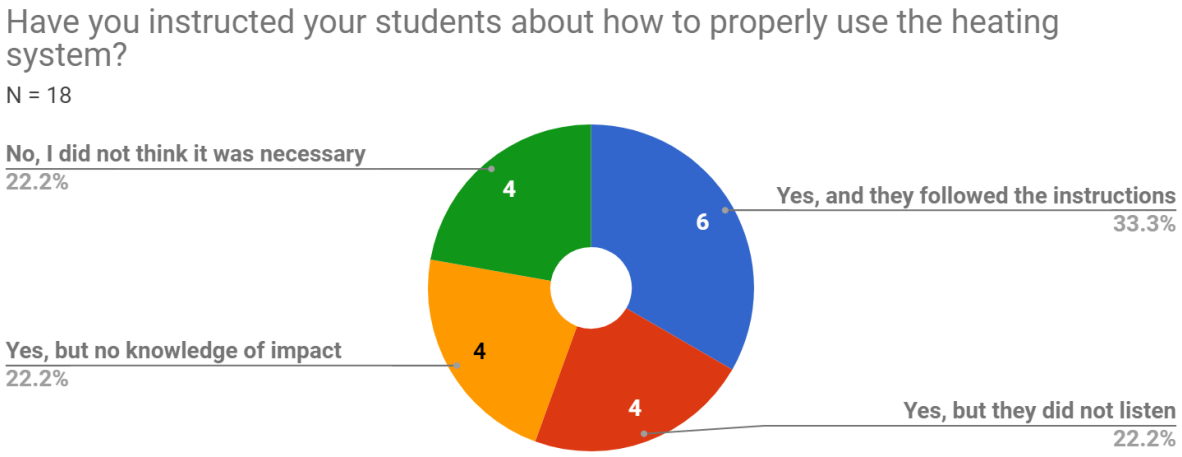

Figure 4.6: Graphic of whether landlords instructed student tenants on how to use the thermostat, and whether the students utilized this information.

Heating Features

This section of the survey gauged the landlords' interest of various features smart heating systems can provide. The scale of the interest was from 1 to 5, with 1 being not interested, and 5 being very interested. For each of these features, a sample size of 16 was received. The Weather Compensation feature received an average interest rate of 93.8%. This meant that 93.8% of participants said that they were either 'extremely interested', 'very interested' or 'moderately interested' in the feature. The Home Presence Detection feature received an average interest rate of 87.6%. The Fault Codes feature received an average interest rate of 81.3%. The Timed Schedules feature also received the same average interest rate of 81.3%. The Energy History Graphs feature received an average rating of 75.1%. The Individual Room Control feature received an average rating of 75.1%. The Mobile Control feature received an average interest rate of 68.8%. For the factors preventing motivation for installing more efficient measures on their homes, 7 said the cost to implement was too high, 2 said there was no demand for the features, 1 said the features weren't useful, 0 said the difficulty to install was too high, and 1 said their residence already had a smart heater. For the methods of learning how to use a smart heating system, 5 said they would prefer reading a user's guide, 4 said they would prefer watching a video, 3 said they would prefer a demonstration provided on the mobile application, 5

said they would prefer an explanation from the installer, and 1 said they were not interested in the system. The figure below displays the results of the interest level of each of the smart heating features, with each color indicating a different level of interest.

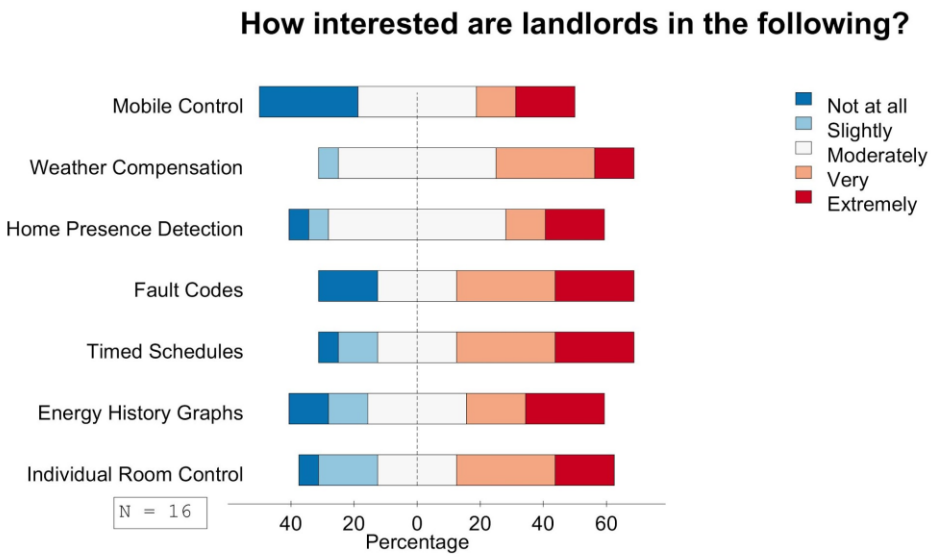

Figure 4.7: Smart Heating Features. A Likert chart displaying the interest level of landlord survey participants in various smart heating system features.

4.1.2 Landlord Focus Group

The focus group for the landlords was held on November 19 from 3:00 PM to 4:00 PM in the Riverside Building at the University of Worcester. The purpose of this focus group was to gauge the interest of landlords and to gain a qualitative understanding of the perceptions of the landlords deeper than what quantitative based surveys alone could provide. The focus group also brought up new topics to consider when making a case for the smart heating system implementation. There were four main groups of questions that were initially set for the landlords to discuss. These main groups were as follows:

- *Tenant Preference*
- *Heat Setup*
- *Tenant Actions*
- *Discussing Upgrades and Efficiency*

Each topic had a few questions to help keep the focus group discussion on the topic. With their consent, the landlords were recorded both by audio and note takers. Using the audio recording and the notes that were taken, the focus group was then coded using a codebook.

Tenant Preference

The first set of questions asked of the landlords was about their tenant preference. These questions related to what type of tenants the landlords prefer to house, be it student or non-student tenants. On top of this, the general consensus for the landlords about tenant preference was also asked.

One landlord answered that there is a tradeoff with housing students; the student tenants brought in more money, but to manage student properties was more of a challenge. This landlord had cited that there were many times when pristine conditions left for the students were often not respected and indicated that they have had student tenants put holes in windows and walls on the property.

On the other hand, another landlord answered that they have had great experiences with students. This landlord mentioned that issues can be brought up to the university, which can be very helpful at times, and that giving good standards to the students builds respect for the students and the properties. This landlord also mentioned that they prefer to do either co-ed or all female lettings, as their experiences with all-male lettings led to the property being damaged.

The last landlord at the focus group mentioned the tradeoff that the first landlord mentioned but stated that they prefer to house families over students. This landlord said that they have had easier times with families because while students change every year, families usually tend to stay in the properties for about 5 years, so they are more responsible and careful of their property. However, they mentioned that students can indeed be charged more, which can make the hassle worth it for some landlords.

Heat Setup

The next section of questions asked related to how utilities, mainly heat, were managed in the rental agreement. This set of questions also related to the boilers themselves, asking how old they are, and what type of heating system it was.

The first landlord stated that the utilities were included in the rent. However, depending on how much of the utilities are used, the rent would be adjusted accordingly. This was done to set competitive rents, and the adjusted rent led to fewer complications with payment for the utilities. As for the heater type and features, the landlord stated that the boilers in their housing were timer operated, so the heater can be set for certain intervals. The boilers of the homes that were discussed included one new boiler, and one old boiler. This landlord believed that boilers are replaced too often, citing that the efficiency gap between boilers is not significant enough to justify the cost.

The second landlord also said that utilities were part of the rent, but it goes through the agent. They said that students prefer this method, as it makes managing the utilities costs much easier. This landlord has only ever had to replace one boiler, and both boilers are around 11 years old. They stated that a replacement will not be made until the boiler has an issue and that the students can control their rooms with TRVs.

The third landlord stated that they only have one property through the University and that the University provides compensation to the landlords for including heat costs in the rent. This landlord also said that they did not know of any other landlords who used exclusive heat costs. As for the boiler, it is also run by a timer, which the landlord sets. This boiler was new when the property was received.

Tenant Actions

The next section of questions related to the student tenants' actions. This was mainly focused on the wasteful actions of the tenants, as well as if the student tenants knew how to heat their property effectively. The first landlord said that the students they housed never really asked about heating methods or how to control the temperature, and were not good at things like maintenance, or contacting their landlord for maintenance or assistance. This landlord said that

they have instructed their students on how to heat their homes with the thermostat, but tells the students to not mess with the boiler timers.

The second landlord said that their student tenants don't ever complain about their temperature, or often ask about temperature when looking for a home. Their only concern is that there is a way to heat the home of some kind. As for instructions, there haven't been problems with a student not understanding the heating systems of the house, even without giving instructions.

The third landlord stated that the tenants were taught how to use the heating systems, and provided written instructions, but is uncertain as to whether or not they get read. However, the students seem to be managing the heat and have no complaints about the heat.

Discussing Upgrades and Efficiency

This final section of the focus group discussed planned upgrades to the landlords' boilers in the future. It also relates to the landlords' thoughts on the efficiency and extra features of new boilers, as well as how they compare to their current boilers.

The first landlord stated that they were interested in some of the features, such as mobile phone control, and individual room control, but was less interested in features like the weather compensation, and home presence detection. They also mentioned that the efficiency gap in the new boilers compared to what is currently installed is not high enough to warrant the cost of a new system. On top of this, they are hesitant to give students high-quality systems since it will not be respected or cared for.

The second landlord stated that they were either indifferent to some of the features like mobile phone control and individual room control, and were not interested in the weather compensation or home presence detection features. On top of this, the landlord does not want to give the student tenants the highest quality systems in order to better prepare them for living conditions after university. On top of this, they saw no reason to replace the boilers.

The third landlord said that they were very interested in the individual room control feature, as the modularity of the system could be very useful. However, for the mobile control, they were indifferent and were not interested in the weather compensation or the home presence detection. They said that they would be willing to look into upgrades if the tenants were

interested, because then the tenants would be willing to use the features to get the most out of the heating system.

Coding the Focus Group

In order to code the focus group for themes, the notes were read through to identify common topics brought up by the landlords. After the preliminary reading, the notes were then read through again in order to find the frequency of each theme. While reading through, if another common topic emerged, the new theme was added to the list, and the frequency analysis was started from the beginning. This was done to make sure that each note was correctly categorized in the theme that it best represented, and also to make sure that each instance of the note was recorded. Once through the notes, the themes were ranked based on their importance to the landlords and were then given a weight factor. Variables such as Cost/Return on Investment, Responsibility/Accountability, Communication, and Competition/Attraction have higher rankings because of their importance to the landlords and are thus weighted more. On the other hand, variables such as Efficiency/Waste, Short Term vs. Long Term and Challenges/Struggles are ranked lower because these were not as important to the landlords, and are thus weighted less. Then, a weighted score for relevance was determined by multiplying the frequency of the theme by its weight factor.

Variables	*Rank*	*Weight Factor*	*Frequency*	*Score*
Responsibility/Accountability	2	2	13	26
Respect/Care	7	1	10	10
Challenges/Struggles	11	0.5	7	3.5
Short Term vs. Long Term	10	0.5	4	2
Competition/Attraction	4	1.5	4	6
Communication	3	2	10	20
Control/Operation	5	1.5	12	18
Knowledge	6	1.5	9	13.5
Efficiency/Waste	9	1	5	5
Cost/Return on Investment	1	2	6	12
Necessity/Replacement	8	1	10	10

Figure 4.8: Weighted Theme Analysis Table for Focus Group

The themes were then sorted and displayed by their weighted score in a Pareto style bar chart, organizing each of the themes from most relevant to least relevant. The relevance of each theme is depicted in Figure 4.9.

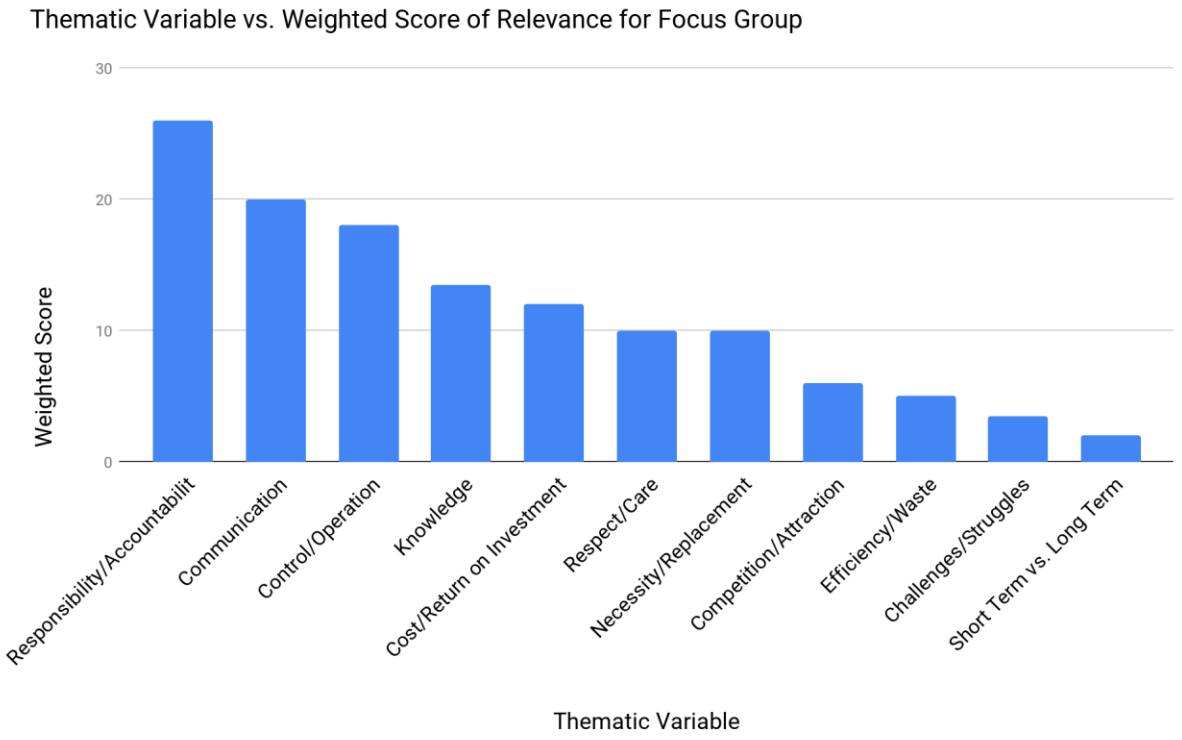

Figure 4.9: Weighted theme analysis chart for focus groups, sorted by weighted score. N = 90 frequency points.

As shown, the most relevant and important theme that came from the focus group was the responsibility and accountability of the landlords to the students. Every time a landlord mentions their perceptions of heat in terms of benefiting their tenants, a mark was tallied. The least relevant theme to the landlord motivations turned out to be the short term versus the long term. This theme involves landlords balancing short-term financial gain against long-term gain. The other thematic elements found from the focus group are also shown in descending relevance order, and their importance will be discussed later in the analysis section.

4.2 Mapping Student Routines

To understand how students attempt to control their heating systems and balance their school schedules, both surveys and participant observation were utilized to attain a greater range of perspectives on the matter. The use of QR codes and survey flyers facilitated the information gathering process, and worked well in busy student centers of the university, like the dining halls and libraries. Through this survey, an ample number of responses was collected and stored for data analysis. We received 65 responses from the students, with a 100% response rate to the surveys distributed via a QR code distribution. The high response rate showed insight about the general behaviors of the students at the University of Worcester in regard to how their life as a student affects their heat usage.

The next facet of this data acquisition process was participant observation. This involved both personal observations and student conversations from the research team living in student accommodations. Over the course of the 7 weeks, the assimilation to student life at this university provided great insight into behaviors students acquired by living in campus housing. These behaviors translate to how students manage their heating systems when busy with their demanding schedules. The combination of these two methods allowed a greater number of results to be collected, which provided greater insight into the problem at hand.

4.2.1 Student Survey- General Questions

The first part of the student survey asked questions regarding student perception of heating and smart heating aspects. There were 16 questions that were asked in the ‘General Questions’ sections, and there was a response rate of 65 students.

Demographic Determination

The first questions laid the framework for the demographic taking the survey and established the age and gender ranges for the population. The chart below shows the distribution for these questions, each in the form of a pie chart. The age range varied from 18 to 22 years old, with 69.8% being females and 30.2% being males. This shows a fairly accurate portrayal of the overall student population at the University of Worcester, as 66.9% of the student population is

female and 33.1% is male. The demographics in the survey had a standard deviation of +-2.05 from that of the actual population at the University.

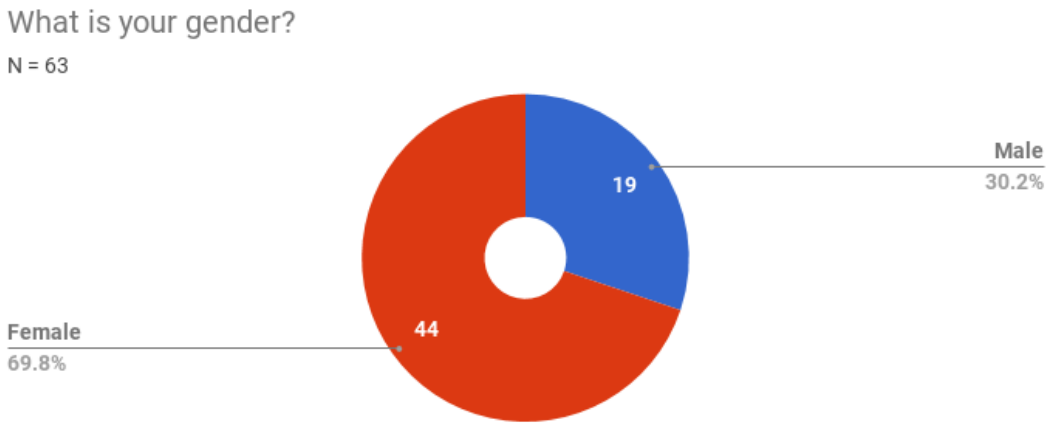

Figure 4.10: Question 2. A pie chart showing the gender of participants.

Housing Framework

The next set of questions identified the setup of the participants specific housing types and features. These questions were needed to distinguish types of housing and other factors in order for correlations to be made between heating and these variables.

To establish the type of housing and the setup of the building, multiple questions were asked regarding housemates and the number of bedrooms. The average number of housemates per building was 7 students, with an average of 8 bedrooms per housing. Since there is a housing regulation in the UK which states that each student must have a single bedroom for occupation, the data showing an even number of housemates to bedrooms is valid. Question 6 of the survey asked, “How many main rooms, not including bathrooms are in your campus housing?”. The average response was that each house had two separate rooms other than bedrooms. These results allow the amount of space and potential rooms for thermostats to be acquired for research, and to see if more living space equates to more complex heating strategies. Another topic covered was the quality of the housing in which the students reside. On average, students said that their current living conditions are, at best, in average condition. This was to be expected, as many of the student accommodations and HMO properties are older properties retrofitted for student living.

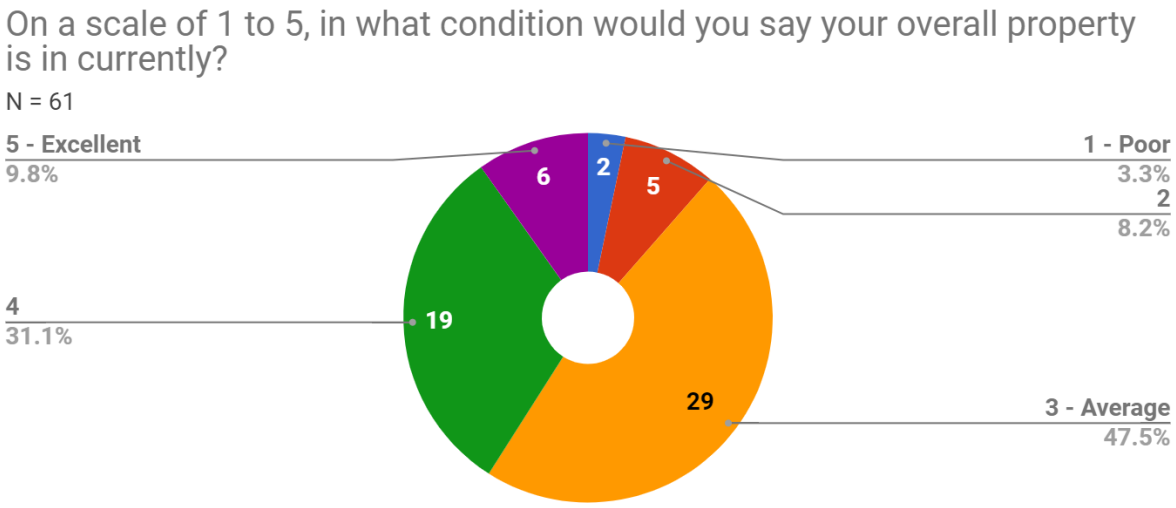

Figure 4.11: Question 7. Ratings of Housing Conditions.

Personalized Heating Experience

A main part of the general student survey was the interactions and perceptions that students have with the heating systems in their student accommodations. These questions include the specifics of students and their interaction with their heating. A major aspect of this is how the heating bill is paid for, and it was discovered that most students have their heat included in their housing rent or fee through either landlord or on-campus housing arrangements. Question 8 of the survey asked students how they pay for the heating in their housing. The most popular response was that the cost of heat was included in the housing cost, with 60.6% of participants selecting this answer. This correlates well with previously collected data, as a significant issue is making the students more aware of their energy consumption when there are no monetary repercussions for excessive energy use.

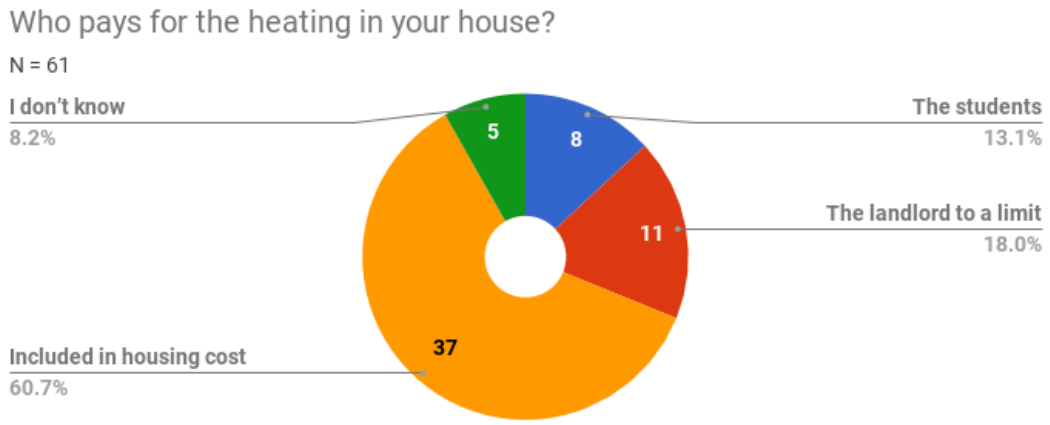

Figure 4.12: Question 8. Responses to how the heat is paid for in student housing.

When asked whether any sort of agent or administrator instructed them on how to use the heating systems in the residence, a majority of students said they had not been instructed. To the question 'Has your landlord, or any other agent, ever instructed you on how to properly use the heating system?', about 3 out of 4 participants selected 'No' as their responses. Out of the 61 responses, only 5 respondents selected 'Yes' for their answer. This indicates that landlords or university housing officers need to more fully inform student tenants about the operation of heating systems and the opportunities that student tenants have to reduce energy.

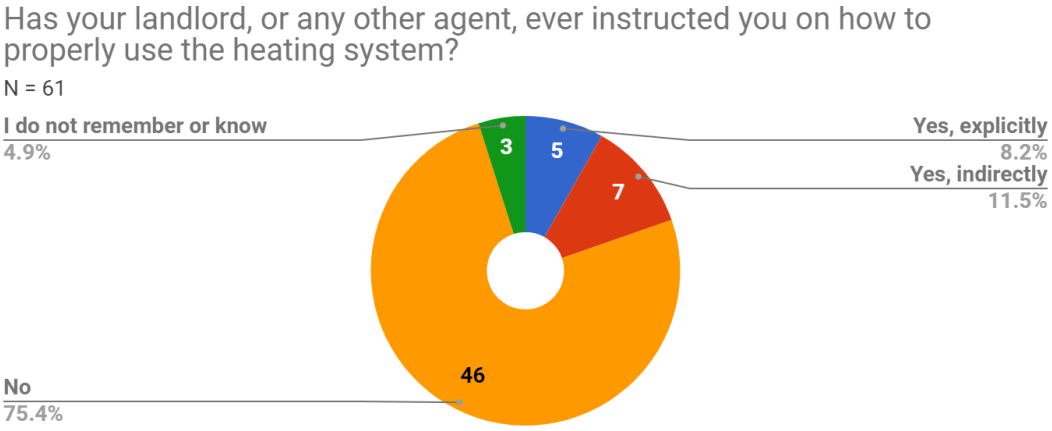

Figure 4.13: Question 11. Responses to 'Has your landlord, or any other agent, ever instructed you on how to properly use the heating system?'.

Other questions in this section involved the physical systems that the students have in their residence, as well as their personal heaters. In order to understand their relationship with heating, knowing their specific types of heating systems is invaluable information. The most popular temperature control was radiator TRVs in each room. A total of 37 students selected that they had radiator TRVs in each room and only 8 selected that they had a smart thermostat with internet control.

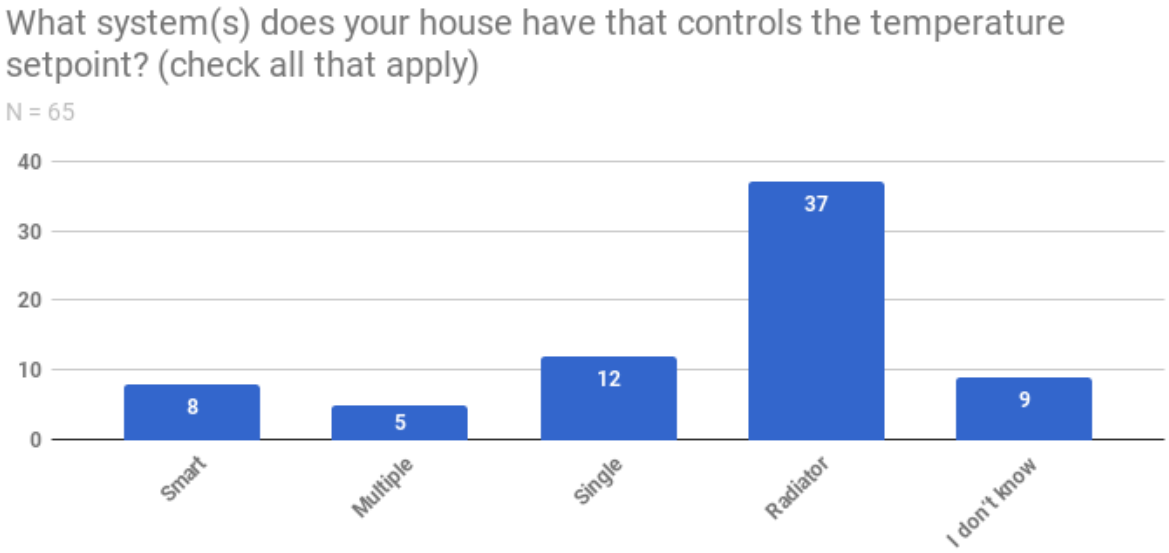

Figure 4.14: Question 9. Responses to how the heat is controlled in student housing.

If 'single thermostat in common space' was selected for this answer, participants were asked to specify where the single thermostat was in their housing. The most common place was in the hallway, with 58% of responses filling it in as their answer. Other answers included the landing or kitchen. This variation reflects the highly variable nature of the placement of the devices.

Multi-Zonal Interest

The pie chart in Figure 4.15 demonstrates the interest level in a smart feature called Individual Room Control. This allows the user to set various temperatures for rooms throughout the house, rather than setting just one temperature for the whole house. As shown in the results

of a previous question, many students do have individual thermostats in their rooms. 77% of participants selected that they would be ‘extremely interested’, ‘very interested’ or ‘moderately interested’ in being able to individually control the heat in their room.

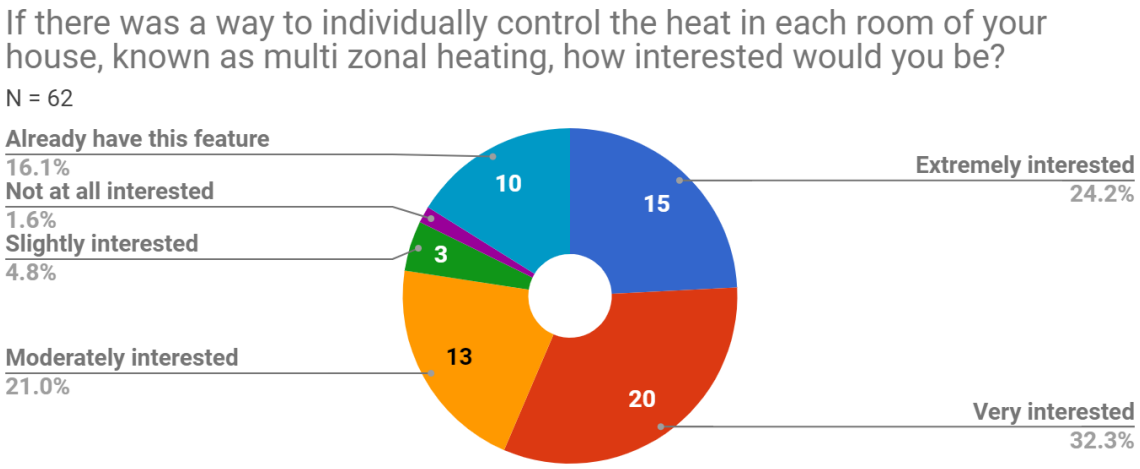

Figure 4.15: Question 14. Gauging interest for Individual Room Control.

10 participants answered that they already have this feature. If they selected ‘Already have this feature’ as their response, then they were given the option to answer an additional question that asked about their opinion of their multizonal heating system. 50% said that the system works well and 30% said that the system works adequately.

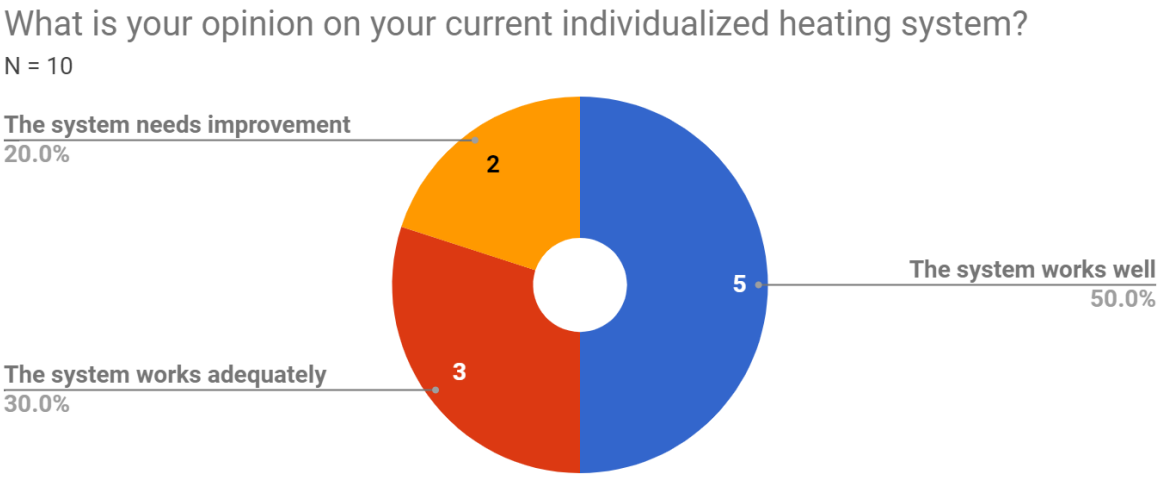

Figure 4.16: Question 14a. Opinions of smart heating systems.

Question 15 asked ‘how often would you control your individual room heat?’, to which 69.4% responded that they would adjust it daily and 3.2% they would never adjust it. Figure 4.17 shows the exact distribution of responses to this question.

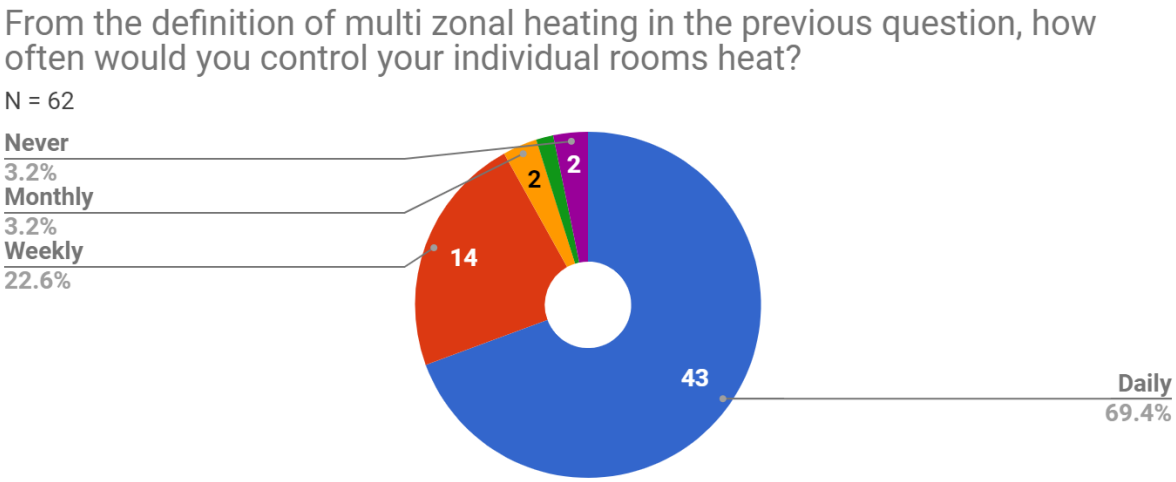

Figure 4.17: Question 15. A pie chart displaying the results to the survey question “How often would you control your individual room heat?”.

Sustainability Concepts

The last set of questions in this section aimed to gather information on the sustainability aspect of the students’ heating. The questions ranged from how sustainable the student's views are, to how students deal with heating in terms of sustainability and energy savings in mind. These questions helped gather information about student behaviors as well as attitudes towards sustainability. Question 10 asked how students dealt with their room being too warm. The two most popular answers selected were ‘Adjust my individual radiators’ (37%) and ‘Open my window’ (35%).

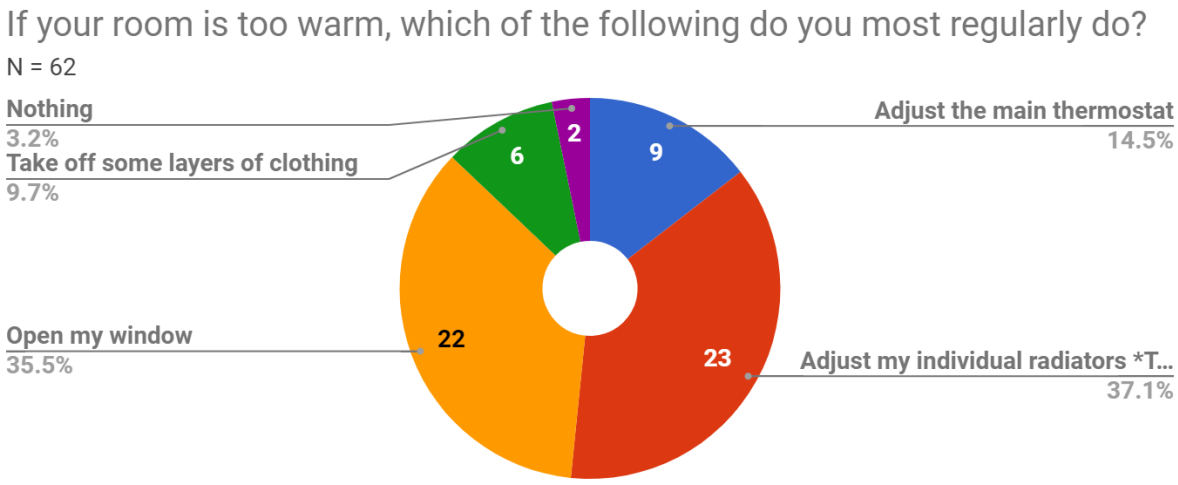

Figure 4.18: Question 10. How students react to high room temperatures.

If students selected 'Open my window' for Question 10, they were then asked why they choose to do this. 15 out of the 22 participants who choose to open their windows when it is too hot to say that the desire for fresh air is their main motivation.

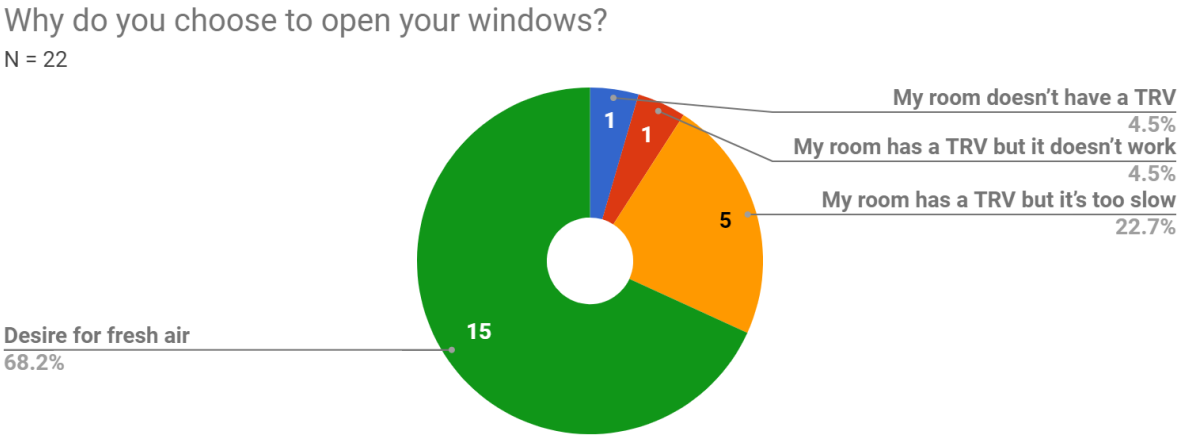

Figure 4.19: Question 10a. Bar graph displaying the main reasons for opening windows.

After asking students about their heating routines, they were then asked if they were ever motivated to be energy conscious with the amount of heat used in their flat. Figure 4.20 shows that 47.5% of participants have never thought about being energy conscious with heat usage and 9.8% have thought about it, but simply think that heating is more important.

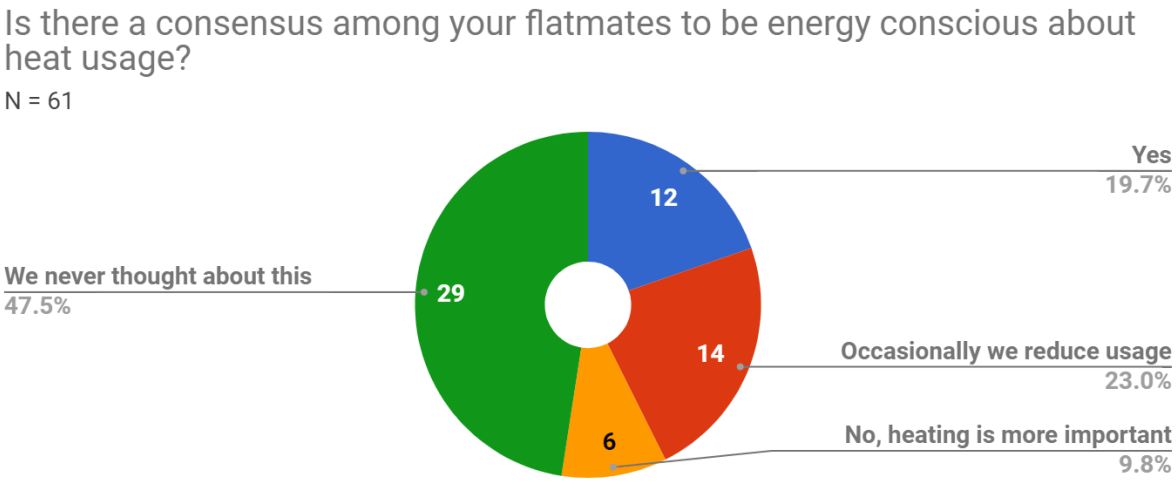

Figure 4.20: Question 13. A pie chart displaying whether students make an attempt to be energy conscious when they use their heating systems.

As follow up questions, participants were asked about their general sustainability knowledge. 67.2% either ‘strongly agree’ or ‘moderately agree’ that they have a good understanding of sustainable concepts. However, only 35.6% selected ‘strongly agree’ or ‘moderately agree’ that their flatmates have a good understanding of sustainable concepts. Figure 4.21 and Figure 4.22 show the results for students’ personal opinion and their flatmates opinions, respectively.

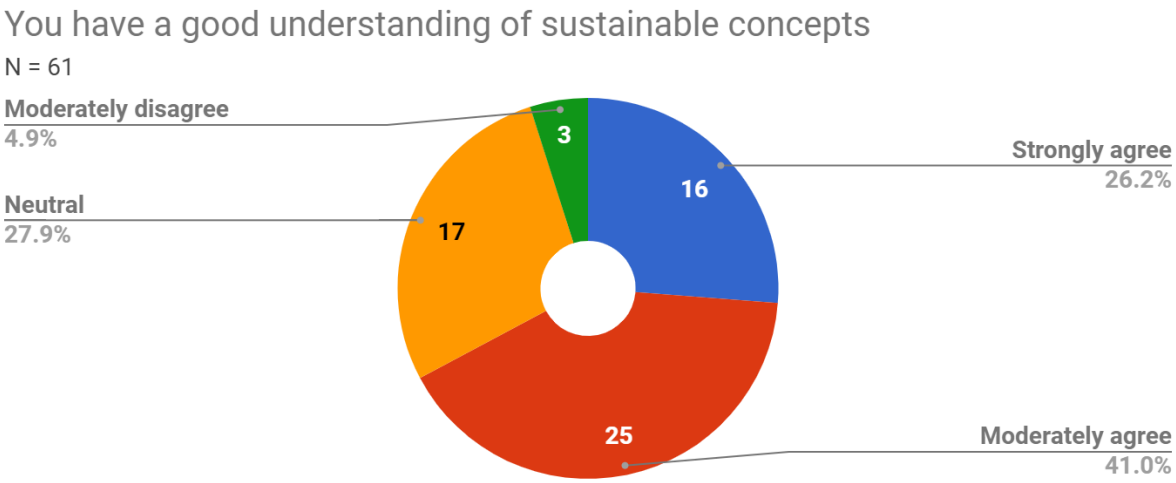

Figure 4.21: Question 13a. A bar graph displaying how strongly participants agree with the statement "You have a good understanding of sustainable concepts".

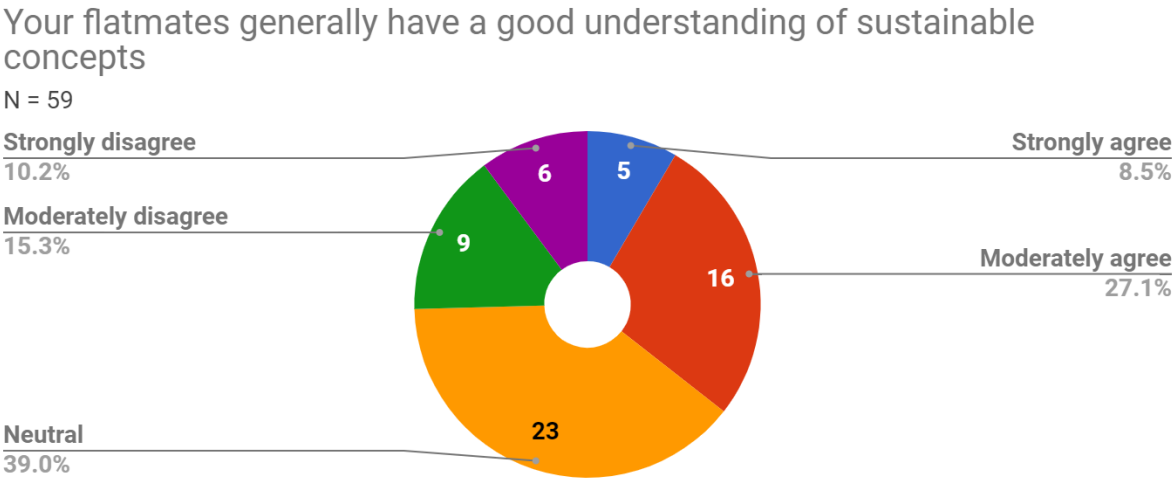

Figure 4.22: Question 13b. A bar graph displaying responses to if the students believe their housemates to understand sustainable concepts.

Relating to these questions is the tracking of energy usage over the course of the heating period. It is necessary information to know if students actively understand, or even have the ability, to see their consumption history over the course of the last billing cycle. The most popular answer to Question 16, 'is there a way to track the heat usage in your house?' was 'I don't know', with 39.7% selecting this answer. 36.5% said that there is no way to track the heat usage.

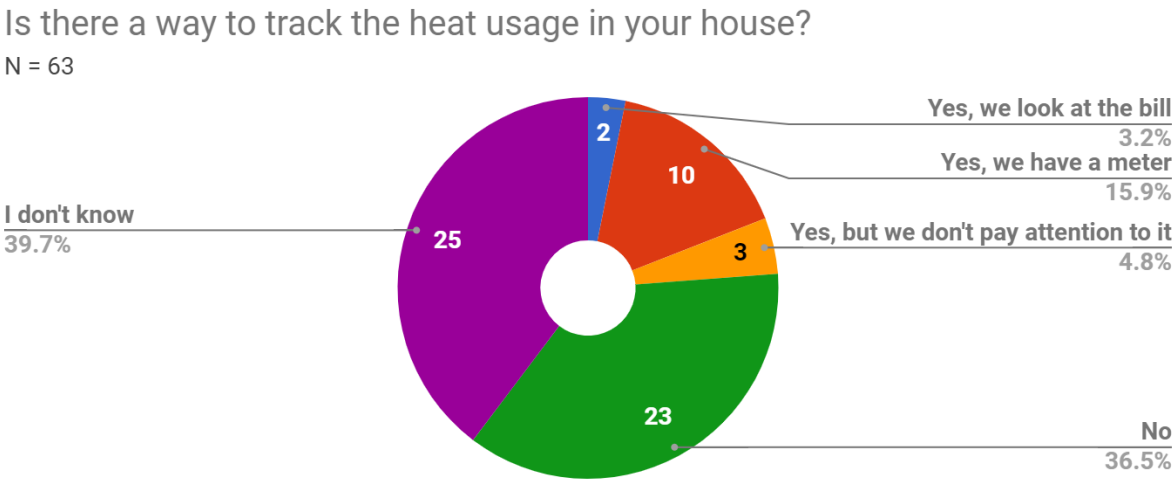

Figure 4.23: Question 16. A pie chart displaying responses to the survey question, "Is there a way to track the heat usage in your house?".

4.2.2 Student Survey- Student Routines

Another section of the survey that was administered to the general student population focused on the routines of students in regards to their heating. There were 58 responses to the overall survey, but this student routines section was the last section of the survey. The 5 questions in this section had an average of 52.2 responses. The results show that most students that took the survey are away from their home for 4-8 hours each day. As shown in Figure 4.24, only 3.4% of students were away from their house for over 12 hours each day.

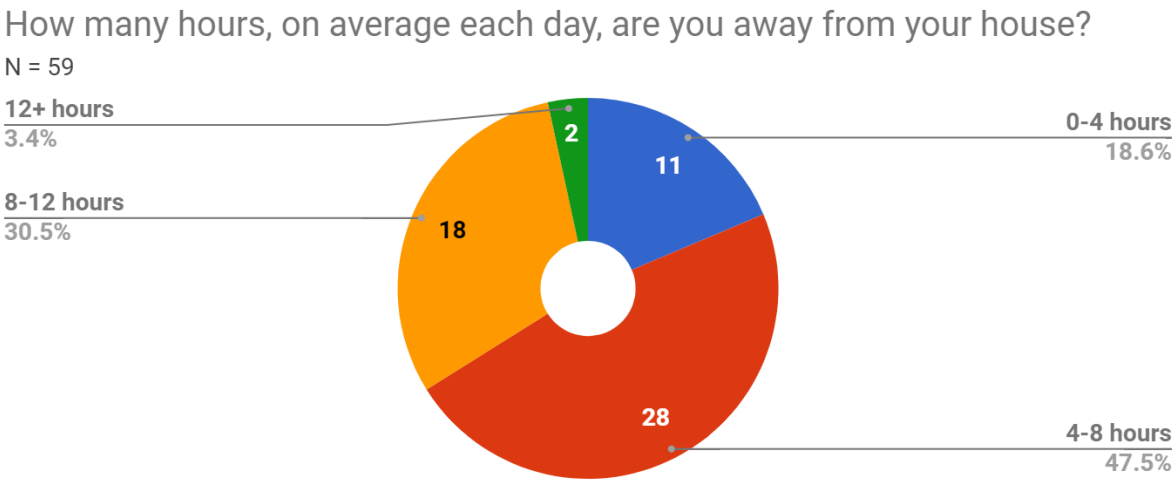

Figure 4.24: Question 27. A pie chart displaying the average time per day away from the house.

The following question asked if the student and their housemates had similar schedules. 46.1% of participant either strongly disagreed or moderately disagreed that they and their housemates had similar schedules. With 9% responding neutral, that left 44.9% of respondents that moderately or strongly agreed that they and their housemates had similar schedules.

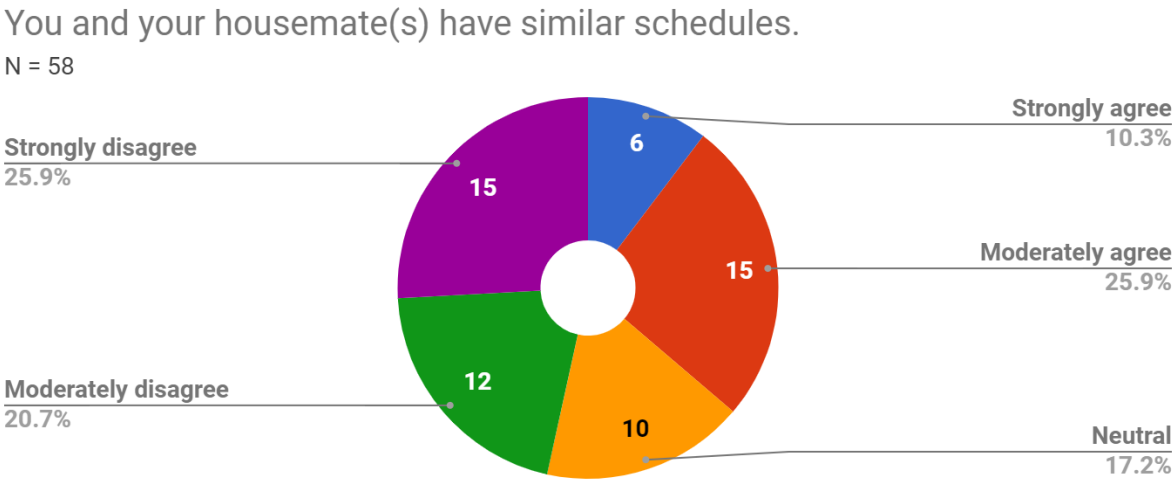

Figure 4.25: Question 28. A pie chart displaying the results to survey question 28.

Question 29 of the survey asked if the thermostat is adjusted when the last person leaves the house. A large percentage (40.4%) said that the thermostat is never adjusted and only 9.6% said that it was always adjusted.

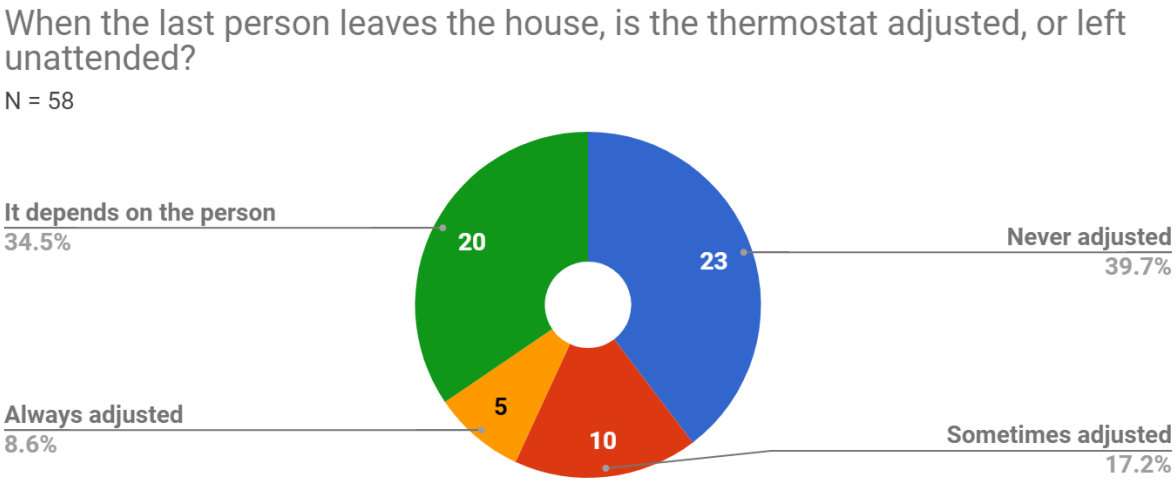

Figure 4.26: Question 29. A bar graph displaying whether the thermostat is adjusted when no one is home.

The behaviors of students regarding adjustments to the thermostat were also surveyed. In question 30, participants selected all the responses that caused them to adjust the thermostat. According to the results of this question, the main reason that students adjust the thermostat is due to an uncomfortable temperature, whether it is either too cold or too hot. 75% of responses said that they actively adjust the thermostat due to uncomfortable temperatures. Leaving the flat had the second highest response, but only 23.1% selected it. This suggests that the main reason for the temperature to be adjusted is due to comfort level.

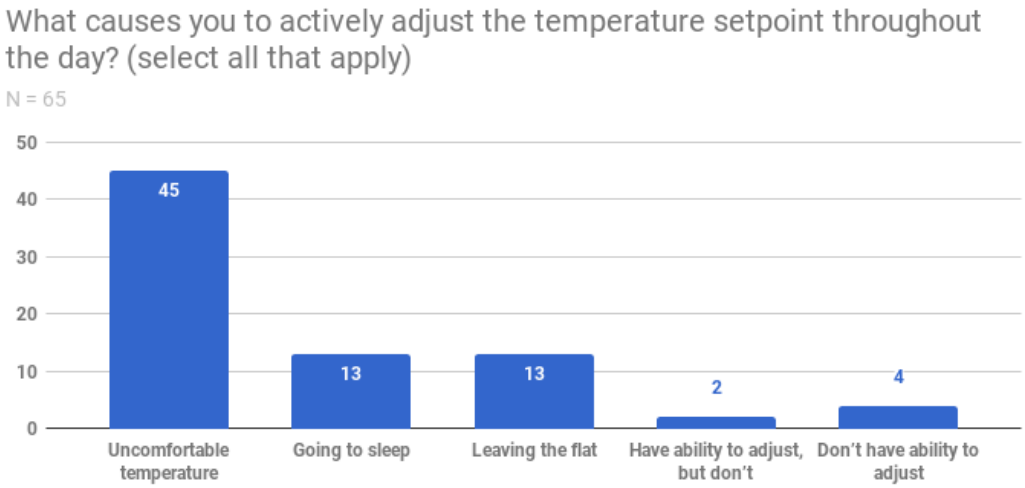

Figure 4.27: Question 30. A bar graph displaying the results to the survey question "What causes you to actively adjust the temperature setpoint throughout the day"

The final question of the survey asked who was in charge of controlling the heat. The most popular answer was that everybody in the flat agrees. 16 people (30.8% of responses) responded with that answer, however, 15 participants said that they had individual thermostats to control their heat. Interestingly enough, only 5.8% of participants said that their landlord controls the heat.

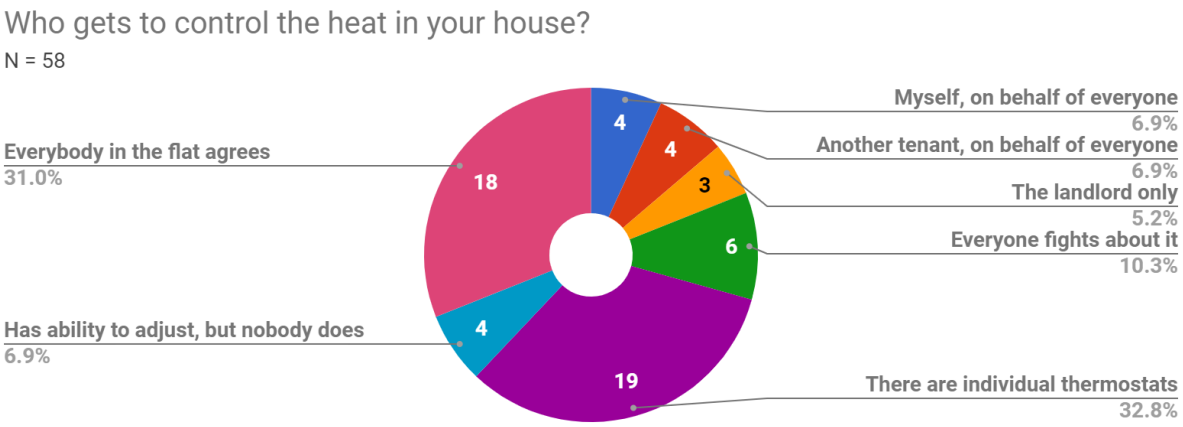

Figure 4.28: Question 31. A pie chart displaying the results to the survey question "Who gets to control the heat in your house?"

4.2.3 Participant Observation

Each member of the research team collected a significant amount of field notes, each containing close to 2 pages of raw data. Each of these notes contained observations, events and other conversations that were witnessed in housing properties. These notes all had time stamps and were collected in different fashions. These individual field notes were combined at a cut-off date, which was November 27th, 2018 and placed into a larger document to allow an easier analysis of the information.

From the assembly of the information, an approximate 8-page document of raw field notes was formulated and consisted purely of observation over the course of the 5-week period (See Appendix F). A codebook was then created to standardize the analysis of the raw data and make the categories easier to understand when taking a quick glance at the data. The codebook can be seen in the figure below. The results of the notes show a consensus about the troublesome nature of the heating systems in personal housing.

Variables	*Rank*	*Weight Factor*	*Frequency*	*Score*
Home Presence	1	2	5	10
Non-active Adjustment	2	2	7	14
Operation/Controls	10	0.5	11	5.5
Active adjustment	3	2	3	6
Comfort/Temperature	5	1.5	10	15
Non-Caring	7	1	6	6
Knowledge	6	1.5	3	4.5
Outside Elements	8	1	7	7
Sustainability	9	0.5	2	1
Schedule Regimen	4	2	5	10

Figure 4.29: The standardized codebook created for the participant observation notes collected

The codebook created combines thematic variables that have been established by the research population, along with the frequency in which these topics were addressed throughout the raw data. The variables selected were predetermined going into the participant observation period, however, varied slightly from after the research period was finished. Reading through the

raw data helped reshape and focus in on the important variables, which allowed a ranking system to be determined. This system takes into account both the importance of the topics from the researcher's standpoint and also from the participant's standpoint as well. For example, the most important variable is the Home Presence of the students, as the main objective is to understand this aspect of the students heating routine. Also, assimilating into the student environment within different types of housing, certain themes had more precedent over others. For example, the topic of actively adjusting the thermostat became a big issue in student housing, while outside elements like the weather impact this data less. This is why these variables are different in the ranking system. This process was applied to each individual thematic variable and also cross-referenced with the results from the survey collected, to come up with the ranking and weight factor system.

After this codebook was standardized, a tally was marked every time the theme surfaced in the transcribed notes. This is shown in the frequency column of the codebook. The most frequent theme that occurred throughout the observations was the Operations and Controls of the thermostat. This was because multiple observations included the difficulty and confusion involving the radiators and thermostat systems utilized. The least frequent variable observed was the sustainability aspect of the students in regards to their heating. Very little was sustainability considered when utilizing the heat. An example of this is leaving the window open due to an easier regulation of the heat in the room. This memo system was used for the entirety of the raw data collected and is displayed fully in the codebook above.

Lastly, a weighted score was created to establish the Relevance of the Theme to the student heating routines. A weighted factor was given to each variable based on its rank factor. The weight factor fluctuates between 0.5 and 2. The more important variables, like Home Presence, has a factor of 2, while a less important factor receives a lower weighting scale. These weight factors are then multiplied by the frequency the variable is seen throughout the notes to receive a final relevance score. From this, a Pareto chart was created to show the relevance and frequency to which each theme is seen within the raw data, and is shown below.

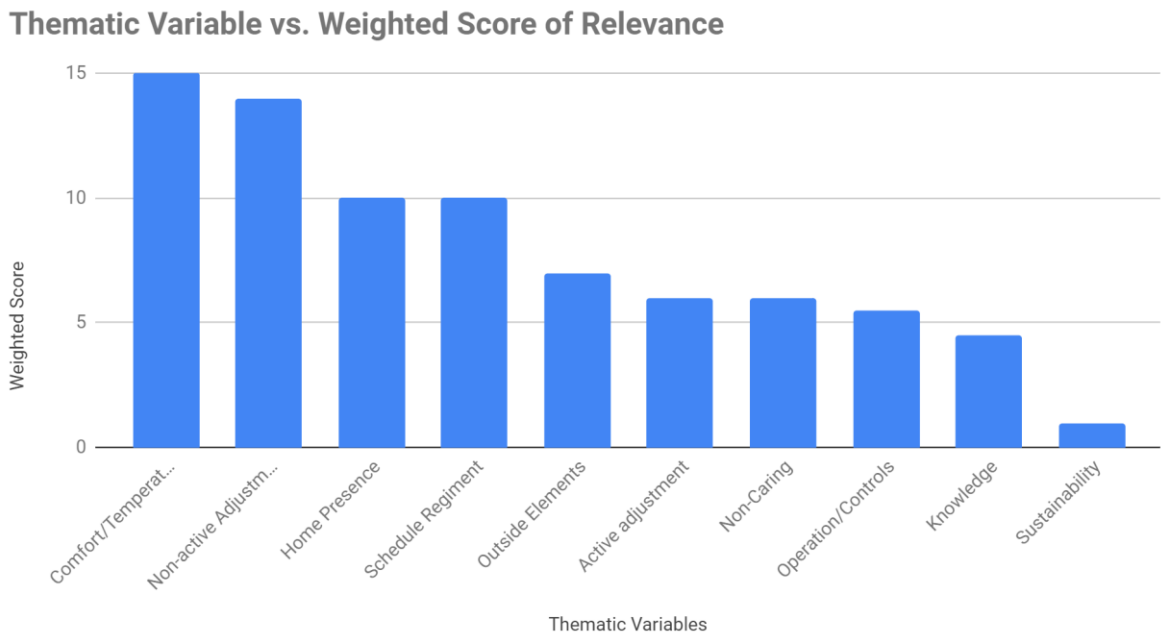

Figure 4.30: A Pareto chart depicting thematic variables versus the relevance throughout the raw data collected. N = 59 frequency points.

The chart shows the scores of each variable in descending order to easily see the relevance of each variable. Comfort and temperature were the most relevant theme to the students in regards to their personal heating routine, while sustainability was the least relevant factor. Each thematic variable and its weighted score are shown in the chart above and explain the relevance to which each of the variables relates to students and how they manage their heat with their busy schedules.

4.3 Student Smart Thermostat Expectations

In order to gather information on attitudes towards smart thermostats among students, a section of the student survey asked questions on specific smart heating features and compared that to the interest level of students. 65 people completed the survey and while this is not statistically significant, it still gives insight into the amount of student interest in these types of systems.

4.3.1 Student Survey- Smart Heating Features

A part of the survey given to the student population focused on views and attitudes towards smart heating systems. This allowed for data to be collected on the interest level of using a smart heating thermostat in student home as well as the specific features that are of most interest to students. In Figure 4.31, the responses to questions 17-23 are displayed. Questions 17-23 discussed the interest level in specific features of Worcester Bosch's EasyControl system. Respondents had the most interest in individual room control feature and the least interest in energy history graph feature. 72.4% of responses were extremely interested or very interested in individual room control, while only 51.7% were extremely interested or very interested in the energy history graphs. Respondents were also very interested in mobile control, with 64.4% being extremely or very interested in mobile control. This is closest to the amount of interest expressed in the individual room control feature.

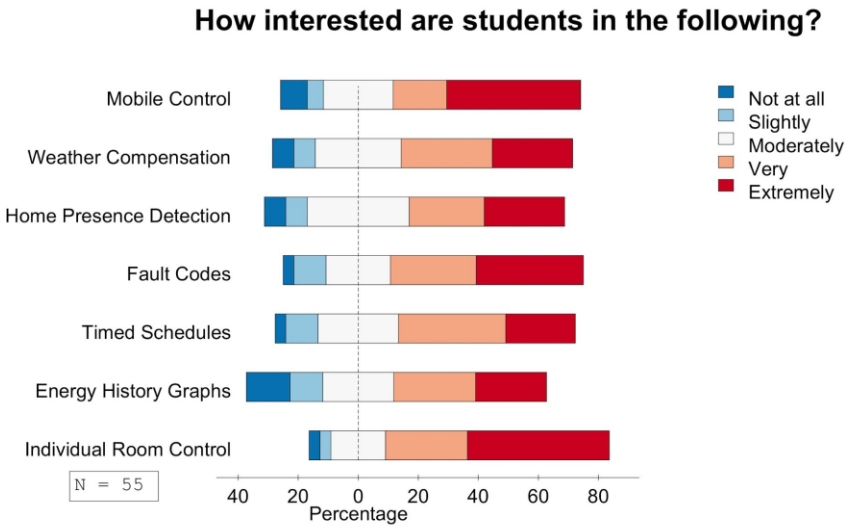

Figure 4.31: Smart Heating Features. A Likert chart displaying the interest level of survey participants in various smart heating system features. n=55.

Question 24 asked how often the participant would use these features if they had them. 50% responded that they would use it daily and 0% responded that they would never use these features if they were available to them.

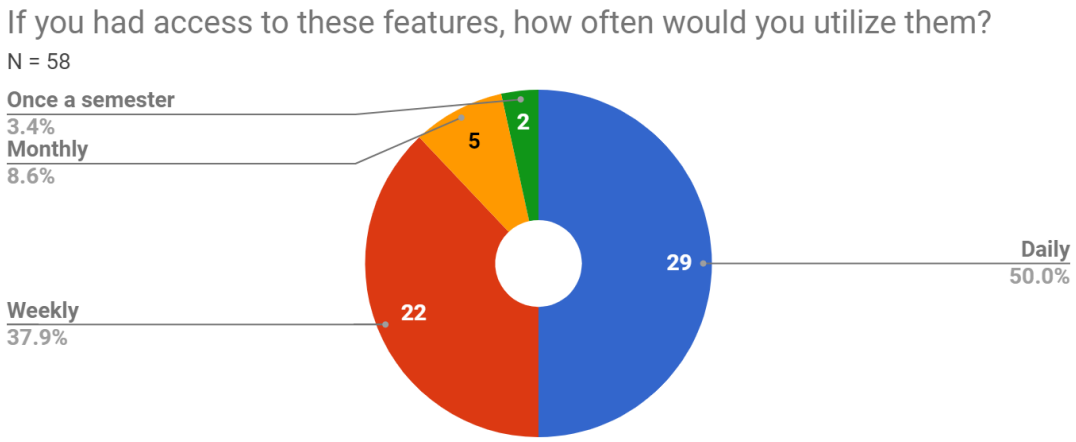

Figure 4.32: Question 24. A pie chart displaying the results to the survey question "If you had access to these features, how often would you utilize them?".

Participants were also asked why they thought that they did not have a smart thermostat already installed in their home by their landlord. 51.7% of participants concluded that the cost was too high to implement for the landlords and 29.3% concluded that it was due to lack of landlord motivation to make upgrades to their properties.

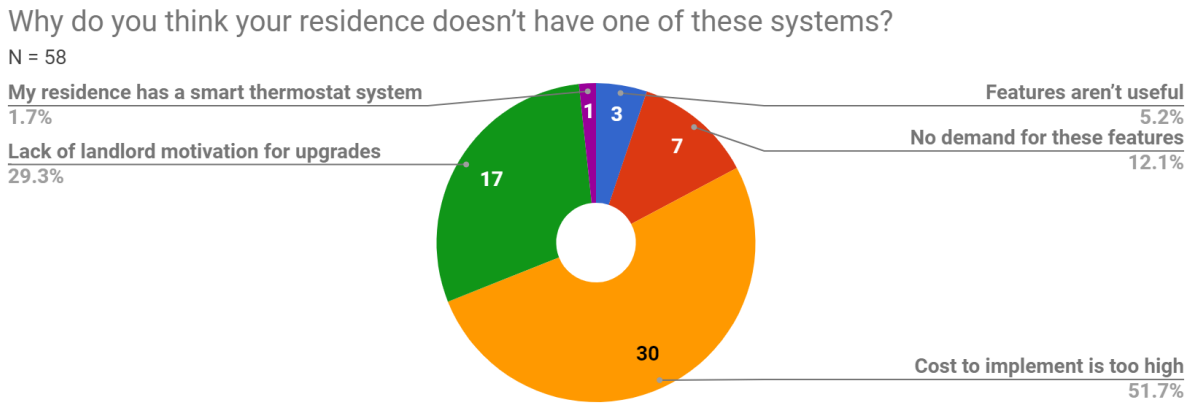

Figure 4.33: Question 25. A pie chart displaying the results to the survey question "Why do you think your residence doesn't have one of these systems?".

Additionally, in question 26, participants were asked which options they would be willing to do in order to learn how to use these systems. They selected all that applied, and the most popular answer was to watch a video. 57.9% of participants said that they would be willing to watch a video and 38.6% said that they would be willing to use a demo/walkthrough that was built into the application.

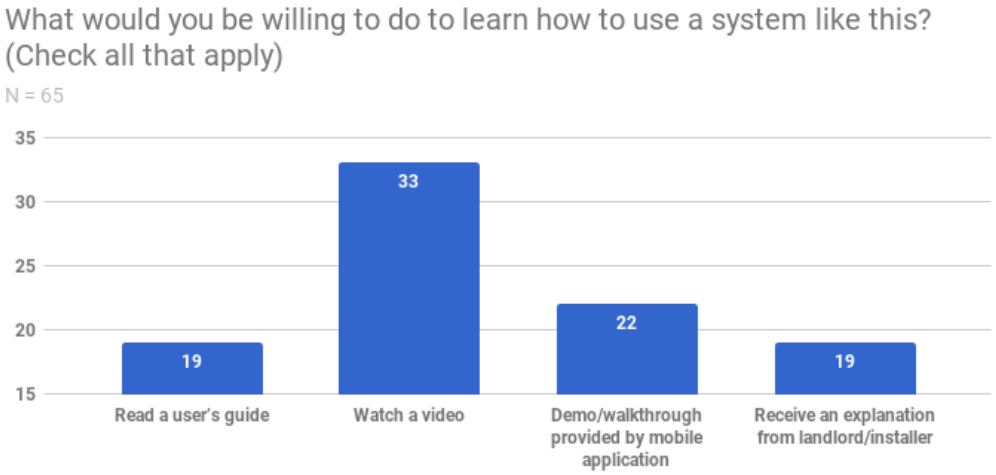

Figure 4.34: Question 26. A bar graph displaying the results to the survey question "What would you be willing to do to learn how to use a system like this?".

4.4 Issues Regarding Letting Agencies

An additional population that was reached out to was professional letting agencies across Worcester, UK. These agencies were contacted about participating in either an interview or a short email survey. Due to the lack of responses from the multiple letting agencies that were contacted, no data was collected from this population. Originally, these two different types of rental agents, both corporate agencies and individual landlords, would have been compared to see differences in motivations. However, this aspect of the research could not be accomplished. A possible reason for the lack of response from letting agencies had to do with the time period in which they were contacted. A first-year student fair for off-campus housing occurred on the only week possible to contact these agencies, and time restrictions proved too difficult to overcome. Future projects must start contacting these agencies earlier with persistent communication in order to receive the necessary information for comparison. While unfortunate, the removal of this population allows a greater focus on the individual landlords that are discussed in the upcoming sections.

5 Findings

In this section, an analysis of the results shown in the previous section is conducted to show the motivations of landlords for more efficient heating systems, as well as student interactions with current heating systems and perceptions of future upgrades. From the data collected in the student population survey, the landlord survey, and the landlord focus group, filters from the Bristol online survey software were used in finding unknown correlations, along with statistical correlation methods that were utilized to interpret the data in meaningful categories.

5.1 Landlord Motivation Analysis

In this section, the responses to the landlord specific survey and the focus group are analyzed to better understand the reasons for which landlords renovate their homes, as well as their perceptions of smart heating systems. Coding the focus group and analyzing the survey responses gave the necessary insight into how landlords perceive these technologies. A better understanding of these reasons allows for a more effective campaign for these upgrades and shows whether or not there is a profitable market for efficiency upgrades in these HMO properties.

5.1.1 Landlord Survey Analysis

The first step in the survey analysis was to create a correlation matrix, which is shown below in Figure 5.1. This chart shows how closely the responses to one question in the survey predicts the response of another questions. Each square represents the correlation between two questions, one on the X-axis and one on the Y-axis. The color changes depending on the correlation, with maroon representing the highest positive correlation and dark blue representing the highest negative correlation, as shown on the scale to the right of the chart. The main diagonal has a correlation of 1 (maroon) because that’s where each question lines up with itself on each axis, and each question has a direct correlation with itself. The entire chart is mirrored along this diagonal.

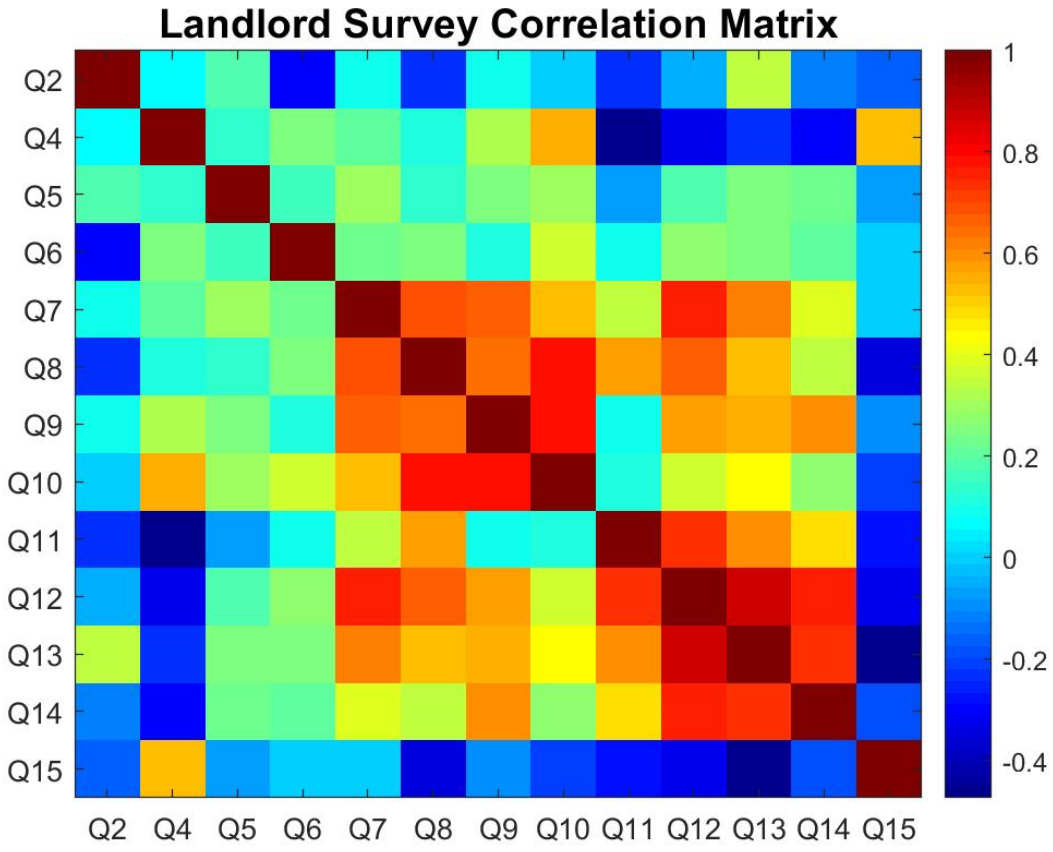

Figure 5.1: Landlord Survey Question Correlation Matrix

The graphic intends to resemble a heat map, with the warmer and colder colors representing positive and negative correlation respectively. This matrix was used to find the questions that were most interesting to analyze in further depth. Due to the responses from 19 landlords, the correlations were less apparent, as many trends had a correlation due to the low number of data points not suppressing random trends.

Correlation of Landlord Responses to Smart Heating Feature Questions

The seven questions related to specific smart heating features were all compared to determine if there were specific trends within this subset of questions. The average response to all features combined was the rank of 2.66, which represents a response of *Moderately interested*. The average response for each landlord is summarized in Figure 5.2a. In addition, the features were ranked from most useful to lease useful as shown below in Figure 5.3b.

The subset of 10 Landlord Responses to Smart Heating Questions N=16		
Landlord	**Mean**	**Stdev**
a	2.29	0.49
b	3.14	0.38
c	3.14	1.35
d	2.71	0.76
e	3.29	0.76
f	3.29	0.76
g	3.71	0.95
h	4.29	0.95
i	3.29	1.25
j	3.29	1.25
Mean	2.66	0.80
Stdev	0.92	0.42

Figure 5.2a: Landlord Response to Smart Heating Features

Landlord Ranking of How Useful a Feature Would Be N=16	
Feature	**Usefulness**
	(Lower Number)
	Most Useful
Timed Schedules	2.64
Weather Compensation	2.73
Fault Codes	2.73
Individual Room Control	2.73
Energy History Graphs	2.91
Home Presence Detection	3.00
Mobile Control	3.13
	Least Useful
	(Higher Number)

Figure 5.3b: Landlord usefulness ranking of smart features

The most useful feature to landlords is the ability to set time schedules for the boiler, with an average rank of 2.64. This wasn't a surprise as this feature was brought up in the focus group as a feature that was regularly used by the landlords who had it as an option. The least useful feature to landlords was the ability to remotely control the system from a smartphone or tablet. This was also an expected result as conversations with the University Accommodations team and the landlords in the focus group showed a general lack of desire to use technology within the landlord population.

There was also a trend in how each specific landlord answered this set of questions. The landlords seemed to respond very similarly to all the different questions. Some were overall more positive or negative, averaging out to a neutral response, but every landlord answered with a similar value for each question. This is shown by the average standard deviation of 0.80, showing that, even though the landlords vary their opinions slightly, the trend is overall positive or negative for each question in the group. This is summarized in Figure 5.2a, which shows the average and standard deviation in responses for each landlord.

Correlation of Boiler Age and If the System has a Smart Thermostat

For all homes surveyed, the age of the home was compared with whether or not a smart thermostat was installed. Out of the 32 homes, five had some form of a smart heating system, with one being in the 0-4-year-old range, three being in the 5-10-year-old range, and one being in the 11-20-year-old. One home in the youngest category, 0-4 years, had a smart thermostat, and only 17% of those in the next newest category had one. The results are summarized below in Figure 5.4**.**

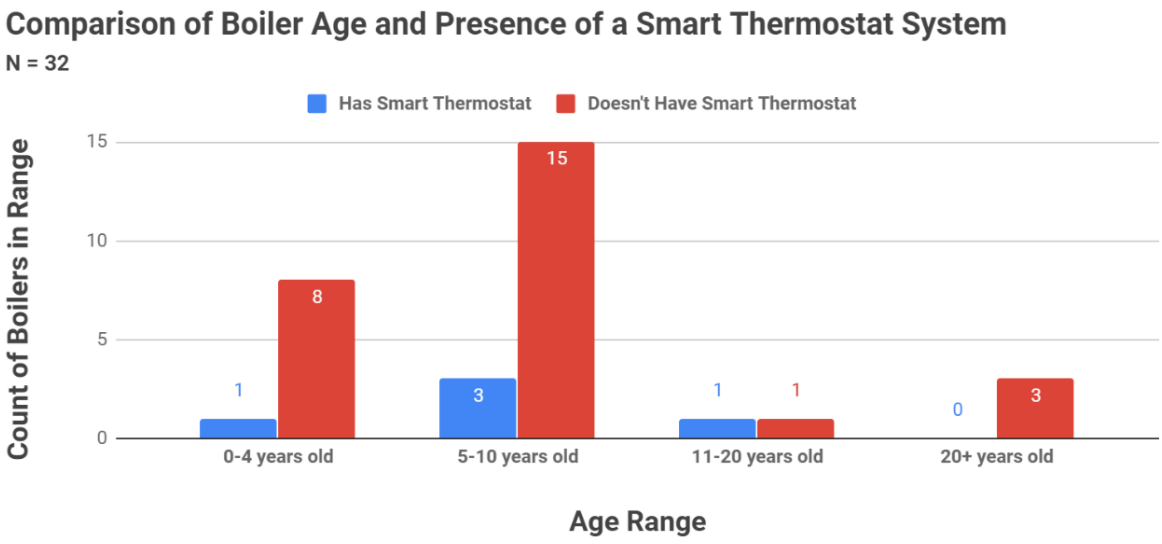

Figure 5.4: Age of Home With and Without a Smart Thermostat

5.1.2 Focus Group Analysis

The focus group played an important role in gathering data. While the surveys were able to gather quantitative data to be analyzed statistically, the focus group was useful in getting qualitative data. On top of this, the focus group brought forth previously unknown issues that the landlords have with their properties.

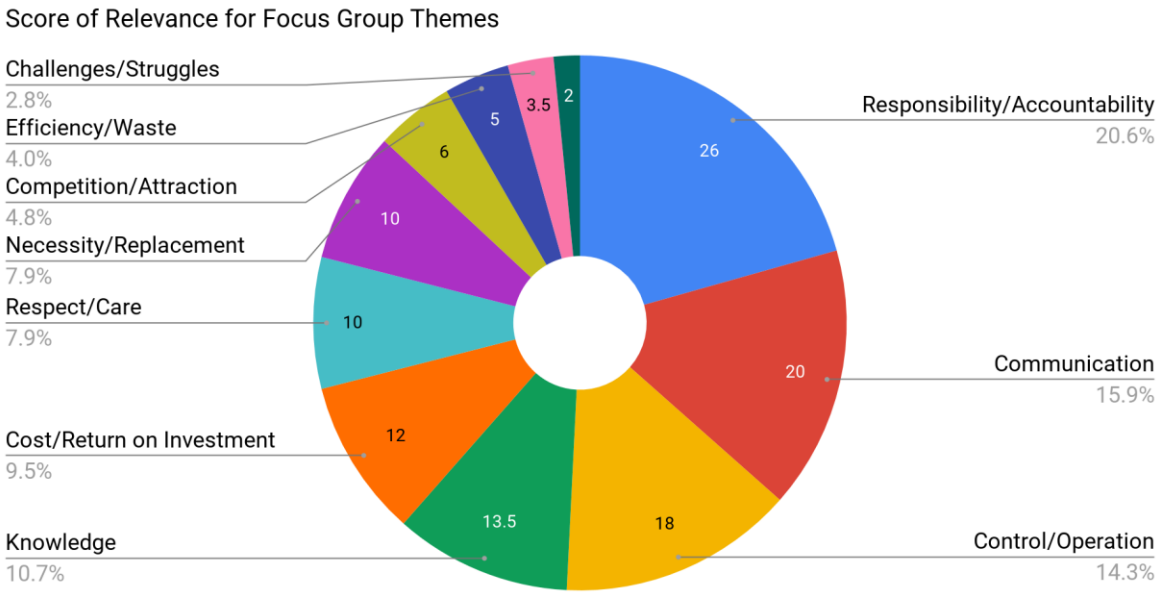

Figure 5.5: Weighted Scores for the Focus Group Themes.

N = 90 frequency tallies.

Based on the weighted score data that was received from the focus group, the four main variables are Responsibility/Accountability, Communication, Control/Operation, and Knowledge. This means that in order to persuade landlords into looking into a smart heating system, these are the four areas of the systems that need to demonstrate strong evidence of utility and value for a landlord. This would involve showing how the system can keep people accountable (Energy Charts), and in good control of the system (Individual Room Control, Mobile Control), as well as easing worries about understanding the system and being able to

communicate with the tenants. Other aspects that are moderately important, but are not necessarily the main focus are the cost/return on investment and potential ways to ensure that students will take care of the new system. Areas that would mostly be an afterthought to the landlords would be how necessary it is to upgrade, how the number of challenges/burdens of letting would go down, and the short-term vs. the long-term of buying the system.

5.1.3 Additional Landlord Forum Findings

The annual landlord forum attended at the end of the research period provided invaluable information that both solidified current findings, and also shed light on topic areas not previously thought about. This event was held at the Guild Hall in Worcester UK on the 6th of December. There were 32 private landlords in attendance which provided a large population for the presentation of research findings and receiving of feedback. While these landlords were not exclusively student landlords, there knowledge and experience in the profession validates their perspectives and opinions. The topics detailed by the landlords in the audience are shown below:

1. Placement of the radiator can have an effect on mold growth and perceived warmth.
2. A demonstration or training program targeted toward the landlord population regarding new technology demonstrations is wanted.
3. Mobile technology, similar to that of the EasyControl App, seems useful to landlords, however, they have not heard of technology like this and aren't sure how to use it.
4. The student landlords had a general agreement on the analysis and findings depicted during the presentation, as they had observed similar behaviors in their tenants.

From the Q&A session held after the presentation, a variety of topics not previously explored were brought up. The first topic mentioned came from the finding that students regularly open their windows to regulate the temperature. A landlord mentioned that the usage of a window sometimes is needed to also regulate humidity within the rooms. Due to the very humid climate and constant heat supplied by the radiator, mold growth becomes a big issue. The location of the radiator also comes into play, as the farther away the radiator is from the window, the more mold that spreads. The placement of the radiator was not previously considered before and might explain why some utilize windows to regulate the heat.

The next two topics mentioned regarded new technology and the interest level for this technology in the landlord population. One landlord mentioned that new heating technology is welcomed, however, is difficult to learn and implement efficiently into properties. From this, the landlord explained the sentiment for a technology workshop or program of some kind involving demonstrations of new technology. An example that came from this conversation was the explanation of the EasyControl smart thermostat system and the associated mobile app. The idea of the system was well received by the landlords, as many wanted to learn about its features and implementation.

Overall, the landlord forum helped to solidify the findings and conclusions discussed within this proposal. Multiple landlords mentioned that they have experienced these findings first hand, like that of student carelessness and communication issues. The forum also helped to reshape some of the recommendations that will be discussed in section 6.2.

5.2 Student Routines and the Effect on Heat Usage

Through the usage of the general student population survey, results for both student housing accommodations and their school schedules affecting their heating habits were found. This data was used to see what factors of a student's routine led to the greatest effect on their heating usage.

5.2.1 Questionnaire Analysis

To begin the analysis for the student questionnaire in relation to student routines, a correlation matrix was created for the specific questions pertaining to routine, just like in the landlord survey discussed in the previous section. This was used to identify which answers would sufficiently correlate with each other to further investigate. Due to the higher response of 65, there were fewer strong trends compared to the landlord survey as random trends were suppressed by the number of responses. Specific correlations are investigated below in Figure 5.6.

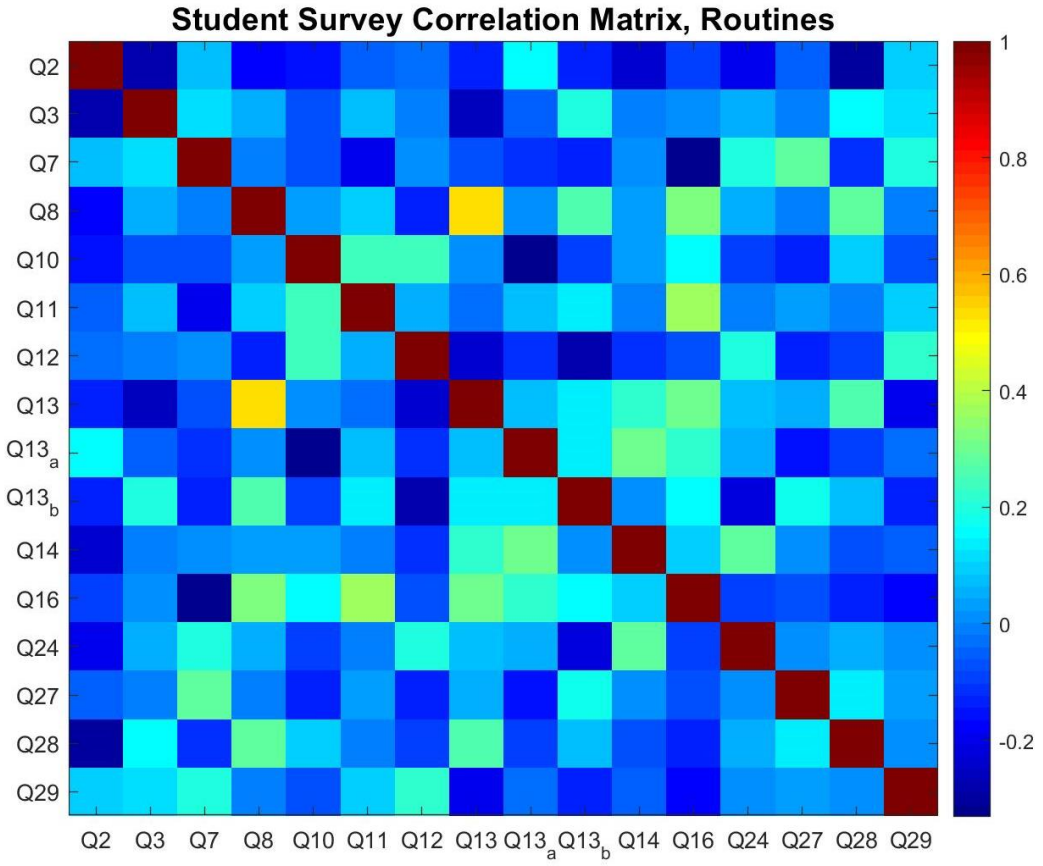

Figure 5.6: Student Survey Question Correlation Matrix for Student Routines

Correlation between who pays for heat and being energy conscious

The questions with the strongest correlation are 8 and 13 which ask about who pays for the heat and if the flat is energy conscious about their heating usage. From background research, this was an expected correlation, since the most consistently identified motivation to save energy was monetary savings. The Figures below show the response to question 13 broken down into the groups who pay for their heating and those who do not. Figure 5.7 shows students who pay for their own heat and Figure 5.8 shows students who have the heat included.

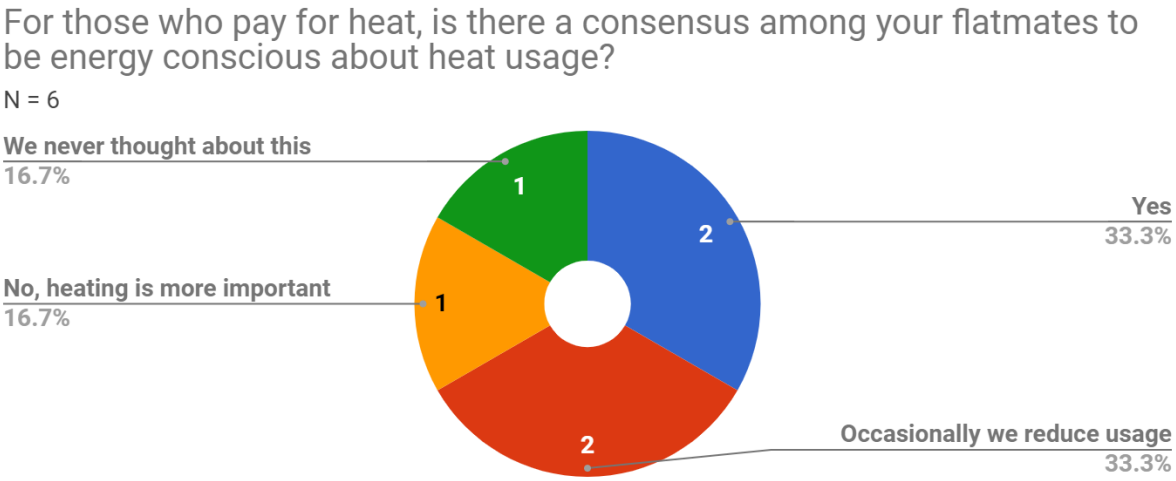

Figure 5.7: How energy-conscious students are who pay for their own heat

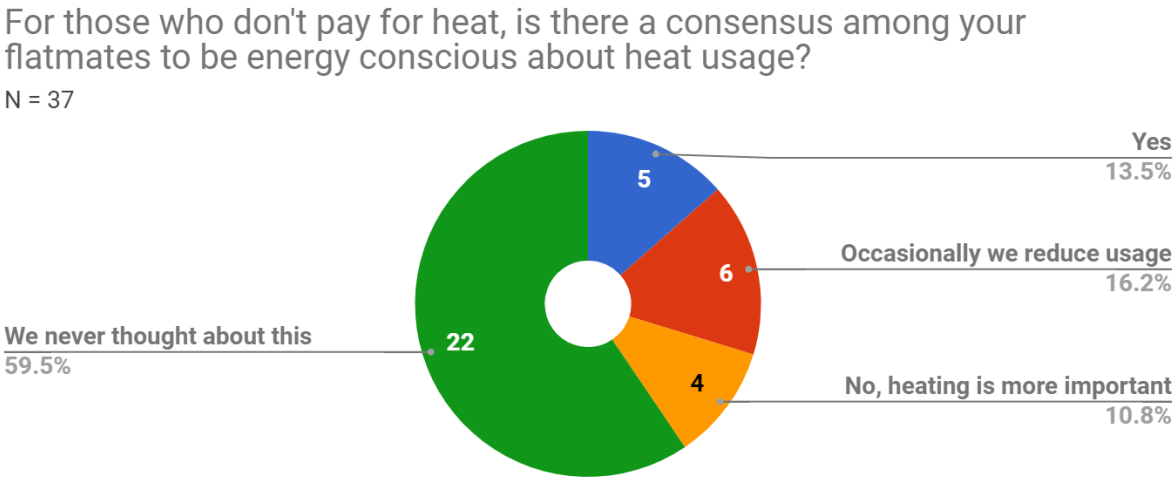

Figure 5.8: How energy-conscious students are who don't pay for their own heat

Of the students who don't pay for their own heating, 60% say they have never thought about being energy conscious about heating usage. This is in contrast to those who do pay for heating who have only 17% of responses saying that this has never been thought about. Those who do pay for heat responded that there is a consensus either always or occasionally to reduce heating 67% of the time, which is more than double the percentage compared to those who don't pay who answered with those choices only 30% of the time.

Correlation between paying bills and being able to track usage

Students were again grouped into those who do and do not pay for their own heating bill, but this time compared to their ability to track their usage. For those who could not track the bill, the largest response was *I don't know* at 44%. This is in contrast to the group who does pay which had zero responses in this category. For those that do pay, 50% of respondents say they check their meter, while only 10% of students who don't pay said this. Overall, students who have to pay separately for their heating and utilities bill are more aware of the resources they have available to track energy usage.

Correlation between gender and similarities of schedule

From the sample collection of the student population, females tend to believe their schedules are more similar to their flatmates compared to males. The summary of responses is shown below in Figure 5.9. Females had an average response of *Neutral* while males had an average response of *Moderately disagree,* a difference of 1 on the Likert scale. Females also had a slightly higher standard deviation of 1.4, while males had one of 1.1.

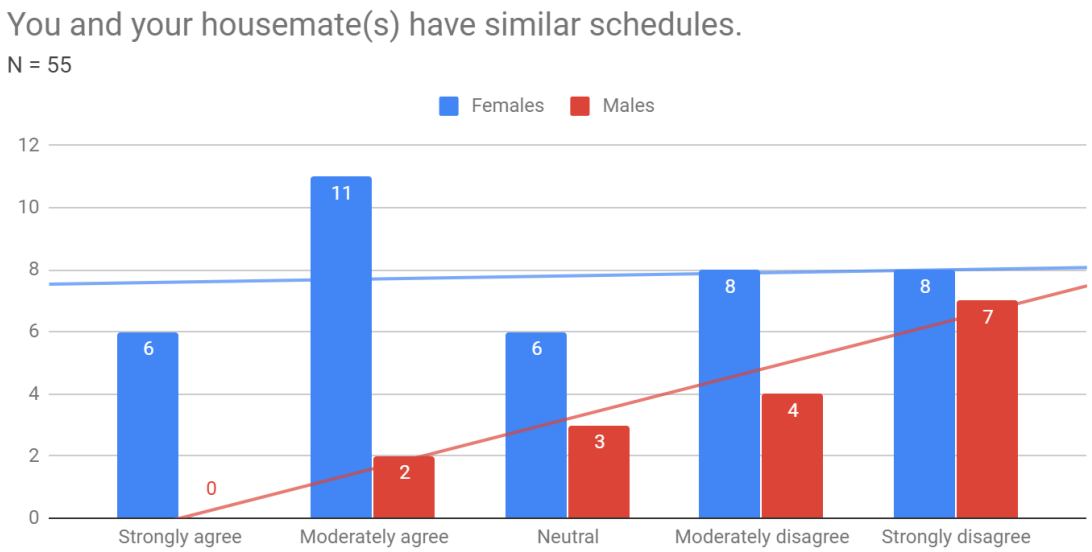

Figure 5.9: Comparison of males and females in relation to schedule similarity

Correlation between Understanding of Sustainability and Unsustainable Practices

By comparing students views on their understanding of sustainable concepts with practices that lead to wasting heat it was determined if students self-rankings were accurate. From the survey data it was determined that, if students regularly open their windows to cool down, as opposed to other more sustainable methods of lowering temperature, their views of sustainable concepts aren't changed. The percentage of students who answered each different category on the Likert scale of how good their understanding of sustainable concepts is differed by only an average of 3%. In this case, students views of sustainability didn't have a large effect on their actual practice of opening windows.

5.2.2 Observational Analysis

Participant Observation amongst students in University of Worcester housing properties allowed a candid look into their specific daily routines. With each of the researchers indirectly investigating the environment into which they were placed, intriguing conclusions were drawn from the raw data collected. From the Pareto chart shown in section 4.2.3, the variable of comfort and temperature was the most prevalent theme throughout the field notes. This variable

was tallied every time a mention or observation of students' adjusting the heat based solely on their comfort level was mentioned. This thematic variable was not ranked highly based on its importance to student routines and heating methods, however, it scored highly due to its frequency within the raw data. An excerpt from the field notes is shown below that describes a comfort and temperature level marking:

Nov. 16

- The roommate said many people just put on/ take off layers when getting too hot or too cold
    - Said no air conditioning because summer does not get hot enough
    - Said heating is less of a worry because of winters not too cold, doesn't fluctuate as much

Nov. 17

- Noticed Thermostat does not get that warm even with max level, so I find it easier to leave the TRV always on max.
    - Sometimes the room is way too warm and other times room is way too cold
        - Needs to be addressed

Figure 5.10: Excerpt from Steven Lussier's field notes taken during the research period

This excerpt shown in Figure 5.10 is an example of a comfort and temperature theme. Every time a note like this was found in the analysis, a mark was made. This thematic variable having the most relevance within the field notes taken meets expectation, as past findings have explained students tend to take their own wants and needs into more consideration over the need to be energy conscious. This is shown in the data as the sustainability thematic variable had a low score. This variable occurred very infrequently throughout the observations as not many of the students mentioned or took sustainable actions. This helps to show that student awareness of energy savings and sustainable concepts has not increased since the last research period. As you can see in the chart below, the two most unsustainable themes, comfort, and non-active adjustment take up the majority of the chart. These two variables combined compose to 36.7% of the distribution. Sustainability, on the other hand, is the small pink section that takes up an insignificant amount of space.

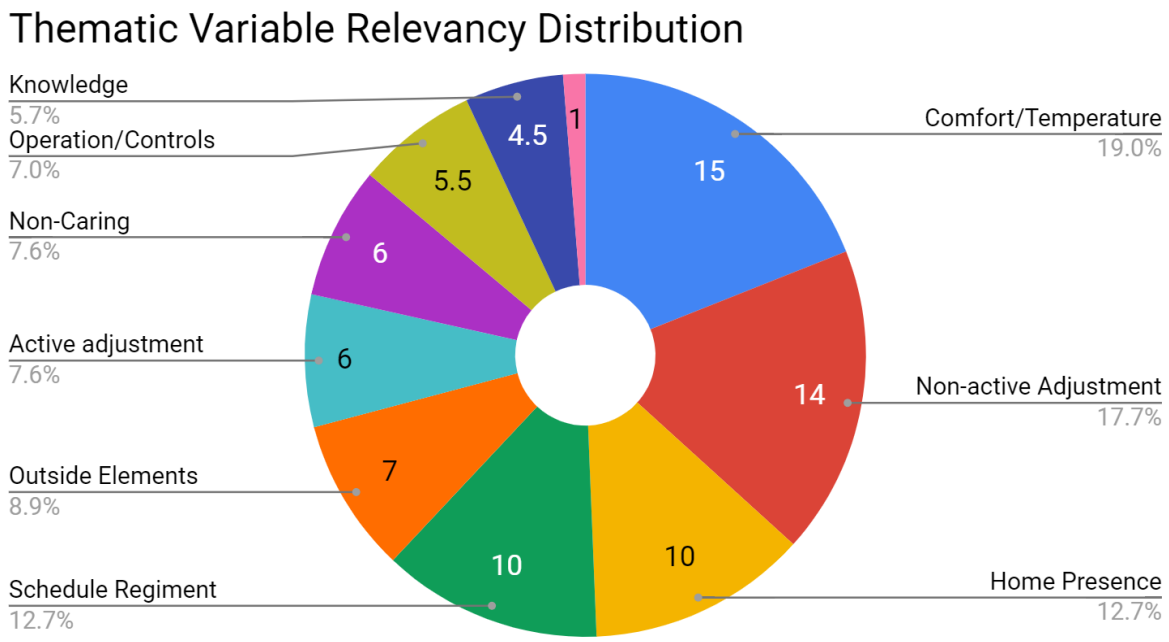

Figure 5.11: Relevancy Distribution of the frequency and weighting factors within the field notes. N = 59 frequency tallies.

The numbers within the chart are the scores found from the multiplication of the frequency of the themes with the weight factor assigned. Sustainability had the lowest score and shows how much less relevant this topic is to students in their daily routines. From the chart above, a majority of the themes that have the most relevancy compound on each other. Student needs for temperature comfort, along with the inactive control and schedule regimen, all combine and paint a picture of the carelessness nature given to heating systems. All these responsibilities add up and make it difficult to adjust the heat, especially when TRV's do not work as intended and require constant adjustment.

Using the codebook and analyzing the field notes allowed the frequency data to be collected. However, a general theme can be understood by analyzing the field notes. Most of the observations and conversations with the student tenants have a negative connotation. Whether the thermostat does not work properly, or the TRV is too much of a hassle, students always seem to have issues with their personal heating systems. From past data, this sentiment holds true. A

consensus from the findings in past reports was made that students do not care about heating as much as they should. These observations notes here help to show that a busy school and social schedule for students makes the active control of the heating systems extremely difficult and non-feasible without an active program of cost or other incentives.

5.3 Student Perceptions on Smart Heating

The following section analyzes the results of students' perceptions of smart heating systems. The data was collected through a survey that was distributed to the University of Worcester's general student population. The section discusses the correlations between the data and presents the most favorable features of smart heating systems, according to student responses.

5.3.1 Smart Heating Features Analysis

Following in the methods of the previous objectives, the specific questions pertaining to smart heating features for students were made into a correlation matrix, as shown below in Figure 5.12. This showed an area of the high trend between all of questions 17 through 24, which are all about specific smart heating features and how often they would be utilized. This set of questions was investigated further.

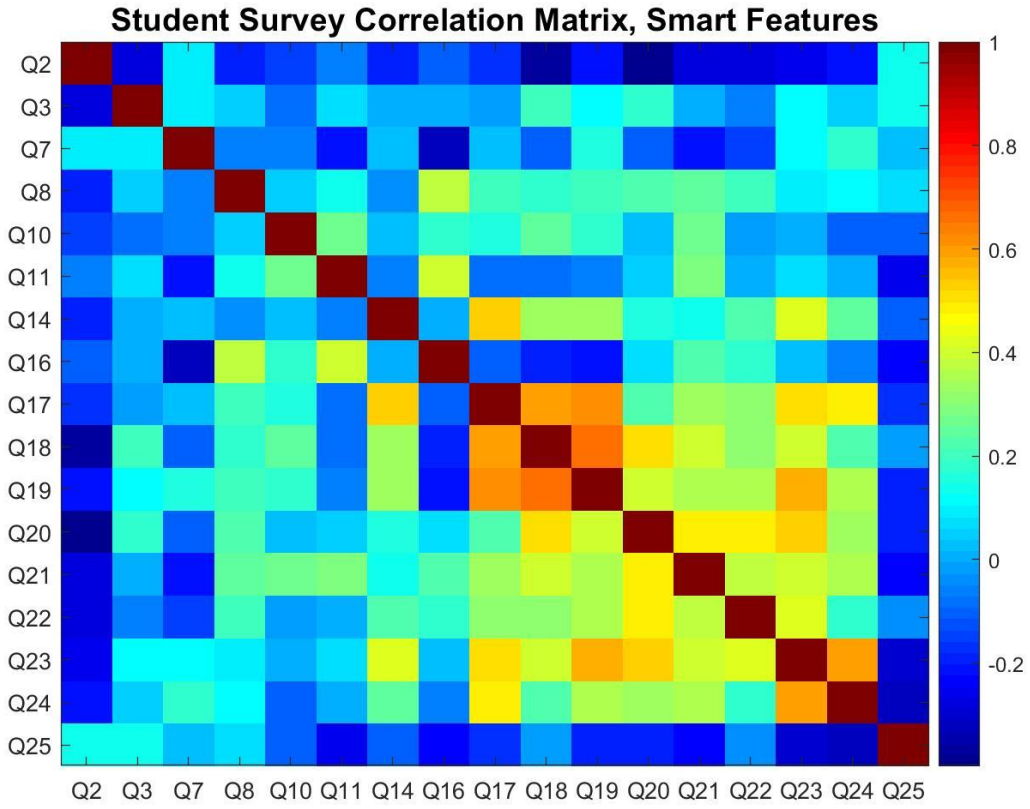

Figure 5.12: Student Survey Question Correlation Matrix for Opinions of Smart Features

Correlation of Landlord Responses to Smart Heating Feature Questions

Just like the landlord survey, the questions on specific smart heating features were analyzed against each other. The students were asked the same subset of questions as the landlords so comparisons could be drawn between their responses. A ranking of perceived usefulness is shown below, along with the relation between the student and landlord responses, shown below in Figure 5.13.

Student and Landlord Ranking of How Useful a Feature Would Be				
N=16		N = 55		
Landlords		**Students**		
Feature	**Usefulness**	**Feature**	**Rank Change**	**Usefulness**
	Most Useful			*Most Useful*
Timed Schedules	2.65	Individual Room Control	▲3	1.89
Weather Compensation	2.73	Mobile Control	▲5	2.15
Fault Codes	2.73	Fault Codes	■0	2.16
Individual Room Control	2.73	Timed Schedules	▼3	2.35
Energy History Graphs	2.91	Weather Compensation	▼3	2.35
Home Presence Detection	3.00	Home Presence Detection	■0	2.42
Mobile Control	3.13	Energy History Graphs	▼2	2.65
	Least Useful			*Least Useful*

Figure 5.13: Summary of Student Ranking of Smart Features Compared to Landlords

The students have an overall different set of priorities in terms of features compared to the landlords. For students, the most useful feature is the ability to control the temperature setpoint in each student's individual room. This backs up the information from background research into previous studies that showed students have a strong desire to be able to set their own specific temperature. The next most useful feature is the ability to control the temperature from a mobile device, which is a large jump from being the least useful feature for landlords. This also makes sense as students are more accustomed to interacting with technology throughout their days. Students are more receptive as a whole to this technology, with the least useful feature being ranked the same as the landlords most useful feature. The least useful feature for students is the ability to view their energy usage from the system. The fact that 85% of students don’t pay for their own heat exclusively means that students don’t have any motivation to see their usage in an attempt to improve it. When the responses are filtered out to only those who do pay for their heat this feature jumps up 3 places, meaning this feature is the third most popular feature. This shows that cost is a large motivation for being energy conscious.

5.3.2 Smart System Ranking

Using the results from the student survey about which features were most interesting, a value analysis system was created and used to give a grade to four different smart heating thermostats in order to determine which one was most desirable for students. Each feature was put into a category and then ranked based on the interest level from the results of the student survey. The order of the ranking system is as follows, with the least weighted category listed first and the most weighted category listed last:

1. Mobile Home Presence
2. Energy History Graphs
3. Weather Compensation
4. Smart Schedule
5. Set Schedule
6. Mobile Control
7. System Error Detection
8. Multi-Zonal Control.

For each feature of the system that fits into a category, the ranking weight of that category was added to the score. The score was calculated by adding up the weighted categories and dividing by 36 since that was the maximum score possible. The system received an A if its score was 0.85-1, a B from 0.70-0.85, and a C from 0.55-0.70.

The features of 4 different smart thermostats were compared using this weighted system. Worcester Bosch's EasyControl System, Neatatmo Smart Thermostat, Momit Home Thermostat and Worcester Bosch's The Wave System were the four thermostats that were compared, as they came from varying companies and had varying features. According to the weighted ranking system, the EasyControl system was the most desirable to students and received an A ranking. This was mainly due to the fact that it had the individual room control feature, which was the most interesting feature for students. Only 2 out of the 4 thermostats in this comparison had this feature and this had the most impact on the grading. Momit Home Thermostat received the lowest grade even though it had the multi-zonal heating feature. It, however, did not have as many other features as the other systems which led to its lower score. The variety of features and multi-zonal capability points to EasyControl was the best match for students out of these four systems.

	Category Score		Category Score
EasyControl		The Wave	
Mobile Control	6	Weather Compensation	3
Weather Compensation	3	Home Presence Detection	1
Home Presence Detection	1	Boiler Codes	7
Fault Codes	7	Energy History Graphs	2
Energy History Graphs	2	Mobile Control	6
Timed Schedules	5	Holiday Mode	5
Individual Room Control	8	Central Heating Optimum Start	4
Total Score: 32/36		Total Score: 27/36	
Grade: **A**		Grade: **B**	
Neatatmo Smart Thermostat		Momit Home Thermostat	
Schedule	5	Smart Schedule	4
Energy Savings Report	2	Mobile Control	6
Mobile Control	6	Presence Detection	1
Auto-Adapt	3	Schedule	5
Auto-Care	7	Individual Room Control	8
Return from Holidays	4		
Total Score: 27/36		Total Score 24/36	
Grade: **B**		Grade: **C**	

Figure 5.14: A value analysis based on categories of the different features of each system

6 Conclusions and Recommendations

This section provides an overall description of the findings throughout the research period. The analysis of the results led to certain conclusions regarding the target populations. From these conclusions, recommendations were arrived at with the intent of having a future positive change in the overall energy consumption throughout student HMO properties. The recommendations are formulated for the sponsors of this phase of Energize Worcester in mind, allowing both Worcester Bosch and the University of Worcester to ponder the implementation of the suggestions provided.

6.1 Summary of Findings

Below are findings that have proven most relevant to this research:

- While students were more interested in features like mobile control and individual room control, the landlords were more drawn to the time schedule set up and the weather compensation features.
- Landlords are interested in keeping tenants responsible and accountable, as well as being able to more easily communicate with their student tenants.
- Most payments for energy are included in the rent for tenant attraction, while this consequently makes tenants less concerned about and, hence, less responsible with their energy usage.
- Based on the interests of the landlords and the students, the EasyControl system is the best system for campus housing.

From an analysis of the student surveys, it was clear that students preferred features that involved more ease in actively managing the heat in their rooms. This was shown by the overall positive interest in individual room control and the mobile phone control features. Meanwhile, the landlord survey showed that they were more interested in features that could be set once and left until a major change was necessary. This is shown by the interest in the heating schedule setups and with interest in the weather compensation feature.

From the coded responses of the landlords in the focus group, the main two categories that were the most relevant to the landlords were Responsibility/Accountability and Communication. This came from the emphasis placed on these themes and the frequency with which landlords referred to them during the focus group. Not only are the landlords responsible for the accommodations, but they want to have good communication with their tenants in order for the tenants to keep them up to date with any matters regarding the property.

According to the responses for the landlord surveys, the most common form of heating setup is having the energy bill be part of the rent. This is mainly done because the landlords want to make their properties more attractive to the tenants, and including the utility bills in the total rent cost is one way to draw them in. However, according to the student surveys, the students with included energy costs are less likely to worry about waste and sustainable usage concepts than those who exclusively pay for their own heat.

6.2 Recommendations

The following recommendations have been made to allow future iterations of the Energize Worcester project to continue and expand upon the work accomplished during this current research period. Multiple different populations were studied in order to allow a multitude of options to be explored. Each recommendation provides ample opportunity for research and analysis, which again allows flexibility for this research endeavor.

6.2.1 EasyControl Installation

After surveying the general student population, there was varying interest found among specific smart heating thermostat features. A clear indication emerged from the data that the most interesting feature to students was the individual room control for multi-zonal heating. However, this feature is not an available option on the current Wave system, which is the system presently installed in five student HMO properties. This is why the research team recommends the installation of EasyControl systems into student HMOs as opposed to the Wave systems currently installed. The EasyControl system has an individual room control feature as well as other features that students expressed interest in. This will allow future Energize Worcester teams to analyze and compare data collected from both the Wave and EasyControl systems.

Comparing these two sets of data would allow correlations to be made and conclusions to be drawn relating to heat usage in multi-zone versus single zone student properties.

6.2.2 Analyzing New Wave Data

Data collected during the winter of 2018/2019 can be analyzed to determine student's energy usage habits. This can be combined with weather data to see how external conditions affect students' usage. To expand upon the study, additional HMOs could be included that are only equipped with a data logging system and not a smart thermostat. This could serve as a control data set which can be compared to the Wave data, as well as EasyControl data when that system is implemented as well. All three of these data points could be compared to see which system is most effective in saving energy.

6.2.3 Letting Agencies

Letting agencies were found to be a difficult population to contact for inquiry. Part of the issue came from the unfortunate timing of the research team trying to contact them during the very busy time when new students were looking at properties for open day. If letting agencies are to be targeted, work must be started earlier to make sure there is ample time to get a response. Many will be resistant to take time out of their day to talk to a researcher. By starting earlier, being persistent, and emphasizing the importance of the involvement of Worcester Bosch, the study could be taken more seriously and a higher response could be achieved. A form of branded apparel may help with this in order for the team to look more official.

6.2.4 Capped Heating Bill

From both survey results, it was concluded that most landlords use an inclusive billing method for their students. This means that when students pay the rent for their housing, they are also paying for heating regardless of how much they have used. Few landlords use the capped heating method, which means that the heating is included in the bill, but students are only allowed to use a specified amount before having to pay an additional fee.

The team recommends that future teams include a study of properties where landlords employ capped heating bills as well as the all-inclusive arrangement. In addition, the team can

investigate the most effective level to set the cap at so that there is the proper level of incentive to save energy. Arrangements, where slightly lower rent are exchanged for capped arrangements over inclusive, could also be investigated so these new arrangements are more competitive for landlords to rent. Exploring these incentives has the possibility to ascertain the efficacy of a capped system in decreasing heating usage and therefore increase the sustainability of the student HMO properties.

6.2.5 Training Program - Technology Workshop

Through this research, it was identified that there are some major barriers affecting the adoption of new technologies and communication between the university and landlords. To address this, a program and workshop could be organized to target these weak points. Topics include, but aren't limited to:

- Organization/restructuring of the university's landlord database to have up to date information.
- Determine more effective forms of communication between the university, landlords, and students.
- Educate both students and landlords about the potential energy savings brought about by new heating technology through the distribution of informative materials and technology showcase workshops. Some kind of giveaway could be awarded for both students and landlords who attend such workshops.
- Educate students looking for accommodations about what to look for in heating systems and how to best utilize them to both maximize comfort and save energy.

6.3 Conclusion

After the data collection and analysis period, many different factors were found to influence the excessive energy consumption of student HMO properties at the University of Worcester. Exclusively choosing one issue as the main problem would be inaccurate, as each problem found compounds on one another to create the overall issue of excessive energy usage. From the findings and analysis, the issues stem from multiple different areas. These are the

student tenants themselves, the student landlords, and the communication systems between the groups.

The students themselves are indifferent about their heating usage and behaviors. This is to be expected, as students in off-campus HMO's are new to independent living, and have little to no experience in day-to-day domestic chores. While an inclusive billing system is implemented to ease the transition of students to living independently, the inclusive nature creates a care-free attitude of students regarding their energy consumption. Many of the current heating systems installed do not help this situation, as they do not provide tenants with much control. The unintuitive heating systems, busy student schedules, and lack of monetary incentives combine to create a care-free attitude among many student tenants.

The other aspect of the excessive energy consumption stems from the landlords and lack of communication between the parties involved. These parties are the students, the landlords and the University itself. The current StudentPad system is not used to maximum effect due to a lack of technological awareness among many current landlords. The communication barrier can be fixed only if steps are taken to implement a better system to accurately distribute information to all.

All the factors described in the above section explain the major issues relating to excessive energy consumption found within this research period. These recommendations were created to allow future Energize Worcester projects to continue to undertake long-term research about this specific topic and to eventually implement a solution to the continuing project goal of increasing energy efficiency for student HMO properties.

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Appendix A: General Student Population Heating Survey

Energize Worcester B18: Student Survey

100% complete

Page 2: Questions

General Questions

Note: This definition is used for some of the questions in this section

**A thermostatic regulator valve (TRV) is the twistable knob on your radiator that allows you to control the flow to your individual radiator*

2. What is your gender? *Optional*

- Male
- Female
- Prefer not to say
- Other

3. What is your age? ✱ *Required*

4. How many housemates, including yourself, do you have? ✱ *Required*

5. How many bedrooms, including your own, are in your house? ✱ *Required*

6. How many other main rooms, not including bathrooms, are in your house? ✱ *Required*

Please enter a whole number (integer).
Please make sure the number is between 0 and 99.

7. On a scale of 1 to 5, with one being poor and 5 being excellent, in what condition would you say your overall property is in currently?

- 1 - Poor
- 2
- 3 - Average
- 4
- 5 - Excellent

8. Who pays for the heating in your house? ✱ *Required*

- You and your fellow students
- The landlord, up to a certain amount
- Included in housing cost
- I don't know

a. If you pay for your heat bill, do you find the price reasonable?

- Yes, it is not too expensive
- It is just reasonable
- No, its too expensive
- I don't pay for the heat bill

9. What methods do your residence use to control the temperature setpoint (check all that apply)? **A thermostatic regulator valve (TRV) is the twistable knob on your radiator that allows you to control the flow to your individual radiator* ✱ *Required*

- [ ] Smart thermostat with internet control (ie. Wave, Nest, EasyControl, etc)
- [ ] Multiple thermostats
- [ ] Single thermostat in common space
- [ ] Radiator *TRVs in each room
- [ ] I don't know

a. What room is the thermostat located?

Please enter a response that only contains letters.

10. If your room is too warm, which of the following do you most regularly do? ✱ *Required*

- Adjust the main thermostat
- Adjust your individual radiators *TRV
- Open your window
- Take off some layers of clothing
- Nothing

a. Why do you choose to open your windows?

- Your room doesn't have a *TRV or other means to adjust temperature
- Your room has a *TRV but it doesn't work
- Your room has a *TRV but it's too slow for my preference
- Desire for fresh air

11. Has your landlord, or any other agent, ever instructed you on how to properly use the heating system? ✱ *Required*

- Yes, explicitly
- Yes, indirectly (ie. in a large packet of information)
- No
- I do not remember or know

12. During colder months, how comfortable, usually, is your flat? ✱ *Required*

- Uncomfortably warm
- Comfortably warm
- Comfortably cold
- Uncomfortably cold

13. Is there a consensus among your flatmates to be energy conscious about heat usage? * *Required*

- Yes, we make great efforts to reduce energy usage
- Occasionally we reduce usage, but it gets difficult to do so during the colder months
- No, heating is more important
- We have never thought about this before

a. You have a good understanding of sustainable concepts * *Required*

- Strongly agree
- Moderately agree
- Neutral
- Moderately disagree
- Strongly disagree

b. Your flatmates generally have a good understanding of sustainable concepts * *Required*

- Strongly agree
- Moderately agree
- Neutral
- Moderately disagree
- Strongly disagree

14. If there was a way to individually control the heat in each room of your house, known as multi zonal heating, how interested would you be? * *Required*

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not at all interested
- Already have this feature

a. What is your opinion on your current individualized heating system?

- The system works well
- The system works adequately
- The system needs improvement
- The system does not work

15. From the definition of multi zonal heating in the previous question, how often would you control your individual rooms heat?

- Daily
- Weekly
- Monthly
- Once a semester
- Never

16. Is there a way to track the heat usage in your house? * *Required*

- Yes, we look at the bill
- Yes, we have a meter
- Yes, but we don't pay attention to it
- No, but we still pay for it
- No, heat is included
- I don't know

Smart Heating Systems

The following section describes a variety of features of a potential smart heating system. Please respond with how interested you would be to have these features in your residence.

17. **Mobile Control:** Ability to adjust the temperature setpoint of the entire house from your phone * *Required*

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not at all interested

18. **Weather Compensation:** The boiler will adjust its water temperature depending on outside conditions to more effectively reach the room setpoint. * *Required*

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not at all interested

19. **Home Presence Detection:** Automatically lower the setpoint to some minimum value when none of the users phones are within a certain radius of the residence ✱ *Required*

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not at all interested

20. **Fault Codes:** The app will give a notification on your phone with any issues reported from the boiler ✱ *Required*

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not at all interested

21. **Timed Schedules:** Ability to set a schedule to automatically adjust setpoint ✱ *Required*

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not at all interested

22. **Energy History Graphs:** Logs of energy use over time that can be viewed on the app to see consumption ✱ *Required*

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not at all interested

23. **Individual Room Control:** Mobile control of the setpoint in your individual room * *Required*

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not at all interested

24. If you had access to these features, how often would you utilize them? * *Required*

- Daily
- Weekly
- Monthly
- Once a semester
- Never

25. Why do you think your residence doesn't have one of these systems? * *Required*

- Features aren't useful
- No demand for these features
- Cost to implement is too high
- Lack of landlord motivation for housing upgrades
- My residence has a smart thermostat system

26. What would you be willing to do to learn how to use a system like this? (Check all that apply) * *Required*

- [ ] Read a user's guide
- [ ] Watch a video
- [ ] Demo/walkthrough provided by mobile application
- [ ] Receive an explanation from landlord/installer

Student Routines

The following section includes questions in regards to your daily routine and schedule here at the University of Worcester. These questions have the aim of finding causation between heating routines and student schedules.

27. How many hours, on average each day, are you away from your house? ✱ *Required*

- 0-4 hours
- 4-8 hours
- 8-12 hours
- 12+ hours

28. You and your housemate(s) have similar schedules. ✱ *Required*

- Strongly agree
- Moderately agree
- Neutral
- Moderately disagree
- Strongly disagree

29. When the last person leaves the house, is the thermostat adjusted, or left unattended? ✱ *Required*

- Never adjusted
- Sometimes adjusted
- Always adjusted
- It depends on the last person who leaves

30. What causes you to actively adjust the temperature setpoint throughout the day? (select all that apply) ✱ *Required*

- [ ] Uncomfortable temperature
- [ ] Going to sleep
- [ ] Leaving the flat
- [ ] Have ability to adjust, but don't
- [ ] Don't have ability to adjust

31. Who gets to control the heat in your house? * *Required*

- You, on behalf of all the tenants
- Another tenant, on behalf of all the tenants
- The landlord only
- Everyone fights about it
- There are individual thermostats
- Has ability to adjust, but nobody does
- Everybody in the flat agrees

Appendix B: Landlord Motivation Online Survey

Energize Worcester B18: Landlord Survey

50% complete

Page 2: Questions

General Questions

Note: This definition is used for some of the questions in this section

***A *smart thermostat* is a thermostat that controls your boiler and connects to the internet to allow control from a users device to change settings and comes with a set of automated features**

2. How many student Houses of Multiple Occupancy (HMO) properties do you have? *Optional*

This part of the survey uses a table of questions, view as separate questions instead?

3. The following questions relate to specifics of your student property portfolio. If you have greater than 3 student homes, please pick the 3 most recently acquired. If you have less than 3, please only fill out to the amount you have.

		When was the boiler last replaced in this home?					Does this property have any form of *smart thermostat controls* (ie Wave, EasyControl, Nest, etc)?		How is the heating bill addressed in your living agreements?			What is the main reason for this set-up?				
	How many students live in this property?	0-4 years old	5-10 years old	11-20 years old	20+ years old	I don't know	Yes	No	Exclusive, i.e. paid by students	Inclusive, i.e. combined with the rent	Capped, i.e. Inclusive to a certain limit	To ensure that pipes don't freeze	Keep heat usage in check	Keep students happy	Other	If you selected Other, please specify:
Home 1																
Home 2																
Home 3																

4. Have you ever looked into installing a **smart thermostat*? *Optional*

- Yes
- No
- I don't know what a smart thermostat is
- I already installed one

a. If Yes, why didn't you have one of these sytems installed?

- Features aren't useful
- No demand for these features from students
- Cost to implement is too high
- Installation is too difficult

5. Do your student tenants ever ask about ways to improve the temperature of their living space? *Optional*

- Yes, frequently
- Yes, occasionally
- Very seldom
- Never or almost never

6. Have you instructed your students about how to properly use the heating system? *Optional*

- Yes, and they followed the instructions
- Yes, but they did not listen
- Yes, but no knowledge of impact
- No, I did not think it was necessary
- I do not remember

7. For you, what is the biggest factor affecting the installation of efficient infrastructure in your HMO property? *Optional*

- Return on investment
- Tenant Attraction
- Sustainability Concerns
- Difficulty of Installation
- Other

a. If you selected Other, please specify:

Smart Heating Systems

The following section describes a variety of features of a potential smart heating system. Please respond with how interested you would be to have these features in your student residence(s).

8. Mobile Control: Ability to adjust the temperature setpoint of the entire home from your students (or own) phones *Optional*

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not at all interested

9. Weather Compensation: The boiler will adjust it's water temperature depending on outside conditions to more effectively reach the room setpoint. *Optional*

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not at all interested

10. Home Presence Detection: Lower the setpoint to some minimum value when none of the users phones are within a certain radius of the residence *Optional*

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not at all interested

11. Fault Codes: The app will give a notification on your phone with any issues reported from the boiler *Optional*

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not at all interested

12. Timed Schedules: Ability to set a schedule to automatically adjust setpoint *Optional*

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not at all interested

13. Energy History Graphs: Logs of energy use over time that can be viewed on the app to see consumption *Optional*

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not at all interested

14. Individual Room Control: Mobile control of the setpoint in a student's individual room *Optional*

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not at all interested

15. Why do you think your residence(s) doesn't have one of these systems? *Optional*

- Features aren't useful
- No demand for these features from students
- Cost to implement is too high
- Difficulty of installation is too high
- My residence has a smart thermostat system

16. What would you be willing to do to learn how to use a system like this? (Check all that apply) *Optional*

- [ ] Read a user's guide
- [ ] Watch a video
- [ ] Demo/walkthrough provided by mobile application
- [ ] Receive an explanation from the installer
- [ ] Not interested

Followup

17. Would you be willing to do a follow up focus group with our team about similar concepts? *Optional*

- Yes
- No

If so, this is only to contact you for a focus group, your name and contact will be kept confidential and not published in the final results.

a. Name?

b. Email address?

Please enter a valid email address.

c. Phone number? *Optional*

Please enter a valid phone number.

The focus group will be held on 19th November, 2018 at 15:00. The location will take place on St. John's Campus at the University of Worcester. The address is St John's Campus, Worcester WR2 6AJ. A follow up email will be sent with more information regarding the focus group details shortly if interested.

< Previous

Finish ✔

Appendix C: Landlord Motivation Paper Survey

#ENERGIZEWORCESTER

University of Worcester

Student Tenant Property Landlord Survey

Greetings,

Energize Worcester is a project sponsored by Worcester Bosch and the University of Worcester. Our team consists of four students from Worcester Polytechnic Institute in the United States. Our research goal is to find ways to reduce energy consumption of off-campus student homes in Worcester, UK and present the findings in a final presentation and paper. With your help, our team can acquire valuable information to help our understandings of motivations to install new and more efficient heating systems into Houses of Multiple Occupancy, or HMO's. Enclosed in this letter is a survey regarding aspects of these heating systems installed in your student tenant properties, and ask for your opinions on the topics discussed. A focus group is also being held on these topics on Monday, November 19th at 15:00, if you would like to participate. This survey has also been emailed to you as well, and the link to the survey is shown below. We thank you for your time and hope you have a good day.

Cheers,
Energize Worcester Research Team

Online survey link: https://ucw.onlinesurveys.ac.uk/energize-worcester-b18-landlord-survey

Informed Consent

You are being invited to participate in a research study. Before you agree, you must be fully informed about the purpose of the study, all procedures that must be followed, and any risks that you may experience as a result of your participation in the study. The study will assist in examining the use of heating systems among students at the University of Worcester. The surveys will be used as well as technical data from Worcester Bosch Wave system in the houses of multiple occupancy (HMOs). This survey contains questions regarding your daily heating routines as well as attitudes towards heating consumption. The survey should not last longer than 20 minutes. This survey is completely voluntary. We do not expect any risk in participating in this survey. At any point, you are free to skip any questions or withdraw from the survey. All information collected will be kept anonymous and will be used in developing our research paper to be published by Worcester Polytechnic Institute. Feel free to ask questions at any point during the interview or after. We can be reached at our email gr-uk-b18-energy@wpi.edu.

WORCESTER Bosch Group

WPI

Energize Worcester Landlord Survey

1. How many student Houses of Multiple Occupancy (HMO) properties do you have? _____

2. The following questions relate to specifics of your student property portfolio. If you have greater than 3 student homes, please pick the 3 most recently acquired. If you have less than 3, please only fill out to the amount you have.

	Home 1	**Home 2**	**Home 3**
How many students live in this property?	# of students:	# of students:	# of students:
When was the boiler last replaced in this home?	☐ 0-4 years ☐ 5-10 years ☐ 11-20 years ☐ 20+ years ☐ I don't know	☐ 0-4 years ☐ 5-10 years ☐ 11-20 years ☐ 20+ years ☐ I don't know	☐ 0-4 years ☐ 5-10 years ☐ 11-20 years ☐ 20+ years ☐ I don't know
Does this property have any form of **smart thermostat controls* (ie Wave, EasyControl, Nest, etc)?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
How is the heating bill addressed in your living agreements? (Exclusive = paid by students, Inclusive = combined with the rent, Capped = Inclusive to a limit)	☐ Exclusive ☐ Inclusive ☐ Capped	☐ Exclusive ☐ Inclusive ☐ Capped	☐ Exclusive ☐ Inclusive ☐ Capped
What is the main reason for this set-up?	☐ To ensure that pipes don't freeze ☐ Keep heat usage in check ☐ Keep students happy ☐ Other, explain	☐ To ensure that pipes don't freeze ☐ Keep heat usage in check ☐ Keep students happy ☐ Other, explain	☐ To ensure that pipes don't freeze ☐ Keep heat usage in check ☐ Keep students happy ☐ Other, explain
Other reason for billing set-up. Please explain in the spaces to the right for each home			

3. Do your student tenants ever ask about ways to improve the temperature of their living space?
   - ☐ Yes, frequently
   - ☐ Yes, occasionally
   - ☐ Very seldom
   - ☐ Never or almost never

4. Have you instructed your students about how to properly use the heating system?
   - ☐ Yes, and they followed the instructions
   - ☐ Yes, but they did not listen
   - ☐ Yes, but no knowledge of impact
   - ☐ No, I did not think it was necessary
   - ☐ I do not remember

5. For you, what is the biggest factor affecting the installation of efficient infrastructure in your student HMO property?
   - ☐ Return on investment
   - ☐ Tenant Attraction
   - ☐ Sustainability Concerns
   - ☐ Difficulty of Installation
   - ☐ Other (Text box given)

Smart Heating Features

The following section describes a variety of features of a potential smart heating system. Please respond with how interested you would be to have these features in your student residence(s). To answer, place a mark in the numbered columns regarding your interest in each feature listed.

1) Not at all interested
2) Slightly interested
3) Moderately interested
4) Very interested
5) Extremely interested

Feature and Description	Interest Ratings				
	1	2	3	4	5
Mobile Control: Ability to adjust the temperature setpoint of the entire home from your students' (or your own) phone					
Weather Compensation: The boiler will adjust its water temperature depending on outside conditions to more effectively reach the room setpoint.					
Home Presence Detection: Lower the setpoint to some minimum value when none of the users' phones are within a certain radius of the residence					
Fault Codes: The app will give a notification on your phone with any issues reported from the boiler					
Timed Schedules: Ability to set a schedule to automatically adjust setpoint					
Energy History Graphs: Logs of energy use over time that can be viewed on the app to see consumption					
Individual Room Control: Mobile control of the setpoint in a students' individual rooms					

6. What would you be willing to do to learn how to use a system like this? (Check all that apply)
   - ☐ Read a user's guide
   - ☐ Watch a video
   - ☐ Demo/walkthrough provided by mobile application
   - ☐ Receive an explanation from the installer
   - ☐ Not interested

7. Would you be willing to participate in a focus group with our team about similar concepts? (This is only to contact you for a focus group, your name will be kept confidential and not published in the final results)

   - ☐ Yes
   - ☐ No

   Name:

   _____

   Email Address:

   _____

   The focus group will be held on 19th November, 2018 at 15:00. The location will take place on St. John's Campus at the University of Worcester. The address is St John's Campus, Worcester WR2 6AJ. A follow up email will be sent with more information regarding the focus group details shortly if interested.

Appendix D: Question Guidelines for Focus Group

General Definitions

TRV (Thermostatic Radiator Valve): A self-regulating valve placed onto a hot water heating system to control the flow of water to the system. These are placed on radiators to allow more control over the temperature in a space.

Multi-Zonal Heating: The ability to separately heat individual rooms in a house. For example, a person could turn off the heat in the living room, while turning the heat up in the kitchen at the same time. This ability is allowed by newer smart heating technologies, like the Worcester Bosch EasyControl

Smart Thermostat Systems: A heating system that is able to be controlled remotely by the use of a mobile device.

Smart Heating Features and Descriptions
Mobile Control: Ability to adjust the temperature setpoint of the entire home from your students' (or your own) phone
Weather Compensation: The boiler will adjust its water temperature depending on outside conditions to more effectively reach the room setpoint.
Home Presence Detection: Lower the setpoint to some minimum value when none of the users' phones are within a certain radius of the residence
Fault Codes: The app will give a notification on your phone with any issues reported from the boiler
Timed Schedules: Ability to set a schedule to automatically adjust the setpoint
Energy History Graphs: Logs of energy use over time that can be viewed on the app to see consumption
Individual Room Control: Mobile control of the setpoint in a students' individual rooms

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You are being invited to participate in a research study. Before you agree, you must be fully informed about the purpose of the study, all procedures that must be followed, and any risks that you may experience as a result of your participation in the study. The study will assist in examining the use of heating systems among students at the University of Worcester. All information collected will be kept anonymous and will be used in developing our research paper to be published by Worcester Polytechnic Institute. An audio recording will be utilized for the acquisition of more accessible notes, however, no personal information will be kept. Feel free to ask questions at any point during the interview or after.

My name is X, and these are my research partners. (State Names) I will be moderating this focus group, along with Y, and (Steven and Noah) will be taking notes and using a smartphone to record the conversation to allow more accessible information.

The questions and topics discussed today will be related to your personal student tenant properties.

Here are some rules and regulations: the discussion will last for about one hour. Please give everyone a chance to express their viewpoints during the discussion. We are only here to moderate and assist the conversation, as you all can converse with the other landlords present. Does everyone understand the logistics of this Focus Group?

Briefly introduce yourselves

- How long have you owned student tenants properties?
- How did you become landlords/property owners

Do you think that there is a preference among landlords for the types of students that they house?

- Do you have a preference for students over other tenants?
- Families?

SPECIFIC PROPERTY QUESTIONS

How many properties do you own?

What is included in your rental agreement? For example, do you include heating in the rent, or do students pay for this separately?

- Do you think that there is a preference for one over the other among landlords?
- What made you choose that setup? Simplicity for you? Student demand for it?
- If your agreement is capped, have you ever actually enforced it?

Do prospective students looking at your properties ever ask about the heating system?

- Ask about the bill? Ask about the system itself?

Do you have any control over how the temperature is set in your rented properties?

● What are the types of heating systems are installed in your property(s)? ○ For example, what set up of boilers and thermostat systems are used?
How old are these systems?
Do your students ever complain about cold and drafty spaces?
● Have you noticed abnormally high heating bills from your students? ● Have you ever noticed the habits of the students that would lead to wasting heat?
Have you told your students the proper ways to heat the property? Have they ever asked?
STUDENT PAD QUESTIONS
Do you think Studentpad is an efficient way for you to advertise your properties? ● Do you use it? Have you ever used it? ● Do you use it exclusively?
Has the service been difficult for you to learn?
Is this an effective way for you to receive communications from the University?
SMART HEATING SYSTEMS
Are you willing to install more eco-friendly smart systems into your properties? Do you have any kind of planned upgrade timeframe for your properties or wait until they break?
● Go through smart heating features slide If you turn your page over there is a table of smart heating features in different properties. We'll go through each one and you can respond with if you think this feature would be useful for you and your students.
Is there a need or motivation for landlords like yourself to install smart systems as referenced above? ● Is this return on investment related?
What improvements could be made to smart heating systems that would convince you to purchase one? To what extent is anticipated cost restraining you from installing such a system?
CLOSING REMARKS
Any final comments?

Appendix E: Focus Group Transcribed Notes

Transcribed Landlord Focus Group Notes

(Names are disregarded for confidentiality)

1. **The number of student houses?**
    a. Landlord 1: 8 years ago. Modern property. Then, bought a cottage and modernized it. 5 Rooms, manage themselves
    b. Landlord 2: 3 student homes. Has an agent that manages some properties. Becomes harder to let with age
    c. Landlord 3: 5 rooms, 8 years ago
2. **Preference among landlords for certain types of tenants (students vs. other)?**
    a. Landlord 1: More money, but more hassle with the students. Has given students pristine conditions that weren't respected. Took up letting as a challenge after retiring. Has had more challenge students, some have put holes in windows/walls (worst year). Very bad experience with some students.
    b. Landlord 2: Happy with students. A great thing about students is you can bring things up to the university. Good standards to the students give respect to the landlord and the property. Has had a much better experience with students than landlord 1. Has tried to do coed letting. All boys setup became filthy, tried to do all girls or mixed. Has done family letting, stay much longer.
    c. Landlord 3: Have students because they make more money.
3. **Is heat included in the rental agreement, or is it paid separately and why?**
    a. Landlord 1: Include utilities in the agreement. Adjust rent accordingly, but it is included in the rent. Set competitive rents, but sometimes make adjustments.
    b. Landlord 2: Utilities are part of the rent, but it goes through the agent. Students prefer it to exclude. Easier to manage utilities from the students. Used to be exclusive.
    c. Landlord 3: Only one property through UW. Get heat money from the University. Doesn't know anyone that has exclusive nowadays.
4. **Control overheat/type of heating system? How old is it?**
    a. Landlord 1: Heater not set for very late. Are run by timers. One old one, one new one. Thinks boilers get replaced too commonly. Thinks the efficiency gap between old and new boilers is not as significant as it has to be.
    b. Landlord 2: Had to replace an old boiler once. Has been fine ever since. Two boilers, 11 years old. Not going to replace them until there is an issue. Students have TRVs.

c. Landlord 3: Heaters run by timer systems in the UK. Set timer late for a late-working student once. The boiler was new when the property was received

5. **Do students ever complain about the temperature of their flat?**
    a. Landlord 1: Never ask about heat stuff. Students not good at running a house, maintenance, or even with contacting landlords. Bad at making requests for assistance.
    b. Landlord 2: Only make sure that there is a way to heat the house. Not concerned with how.
6. **Have you ever noticed abnormally high heating bills?**
    a. All do not notice the bill
        i. Can not see the usage as the university takes care of the billing
        ii. Along with letting agencies
7. **Have you instructed your students how to heat their property?**
    a. Landlord 1: Shows tenants where / how to use the thermostat. One boiler managed by a timer and told tenants not to mess with it. This property run by UW.
    b. Landlord 3: Has instructed students on how to heat the house. Written instructions, not sure if they read the instructions. Seem to be doing fine.
8. **StudentPad**
    a. Landlord 1: Don't really use StudentPad too much. University can be slow with its communication. Hasn't had problems with talking to students.
    b. Landlord 2: Uses StudentPad too much. No problems with the site. Can use email for questions about properties through the account. Have to go through UW to talk to the students. Need to give 7 days notice before going to the properties.
    c. Landlord 3: Never used StudentPad. UW doesn't like students communicating directly with the students.
9. **Planned Upgrades**
    a. Landlord 1: Replacements requires quality choice. Doesn't like to give quality upgrades to student homes because students don't respect it as much.
    b. Landlord 2: Usually doesn't make changes when something still works. May make changes when students leave for convenience.
    c. Landlord 3: Usually does not upgrade boilers unless an issue comes up. Has thought about installing smart heating systems. Has one at home, really likes it. Likes the features. Not sure about how students would use it.
10. **Smart heating system features**
    a. Mobile Control
        i. Landlord 1: Had not considered the usefulness of controlling with a phone. Not something to dismiss can see the benefits.
        ii. Landlord 2: N/A

iii. Landlord 3: N/A

b. Weather Compensation
    i. Landlord 1: Don't seem too interested
    ii. Landlord 2: Don't seem too interested
    iii. Landlord 3: Don't seem too interested
c. Home Presence Detection
    i. Landlord 1: Used to advise students to leave boilers running on low keep pipes from freezing
    ii. Landlord 2: Usually has one student stay home, rarely empty
    iii. Landlord 3: Houses rarely empty, one person stays sometimes.
d. Fault Codes
    i. Landlord 1: N/A
    ii. Landlord 2: N/A
    iii. Landlord 3: N/A
e. Time Schedule
    i. Landlord 1: N/A
    ii. Landlord 2: N/A
    iii. Landlord 3: N/A
f. Energy History Graphs
    i. Landlord 1: Not interested in this feature.
    ii. Landlord 2: Not interested in this feature.
    iii. Landlord 3: Not interested in this feature.
g. Individual Room Control
    i. Landlord 1: N/A
    ii. Landlord 2: N/A
    iii. Landlord 3: Likes the modularity of the system, and how it can be easily scaled.

11. Incentives to buy a smart heater

a. Landlord 1: If the general expected level of provision is raised to smart heater levels, it would be a good thing to put in place. Not sure if students would know how to use the features though. Lots of other things to learn at University
b. Landlord 2: Students seem to have too much. Should be a transition between home and the real world. Worried that students will not be prepared to live if there is too much for students. Students used to cut the grass, but now students cannot use mowers. Comforts might not be good long term.
c. Landlord 3: If tenants expected it, it might be worth looking into, knowing that they have an interest in the technology, and would know how to use it.

12. Time-frame for Renovations

a. Landlord 1: 4 weeks about. Starts 1st of July, even though no one wants to stay there
b. Landlord 2: 6-8 weeks, can pay to stay over the summer. 11-month agreement to allow for renovations to be made. Becomes harder to be useful when the University is involved with restrictions. Fewer problems with student tenants as they spend more time in the houses.
c. Landlord 3: 4 weeks or so, when students are gone.

Other Major Topics Discussed

Smart heating systems

Landlord 1:

- Thought about it
- Likes the idea very much due to settings
- Wonder whether if it will benefit students at all
- Worried about security and if it would harm students
- All have TRV on the radiators

Landlord 3

- knows students use the TRV all the time
- Feels that the fewer students have the worry the better because students are useless
- Students don't clean house even,
- Says tensions build up between students, so say want students to have less to worry about
- All have only one thermostat in the kitchen or landing/ none have smart thermostat systems
- Same thing as living in the family home

Landlord 2

- has not considered it
- Got new boiler through Bosch
    - briefed him on it and gave pamphlet on it no follow up
    - Just got a smart meter, says he is a little late to the smart party
- Is not against smart thermostat, but would like to see the improvements
    - Are interested in smart, but want to see benefits
- Security big issue amongst three landlords

Landlord 1

- Says doesn't need to see the history of the heat usage
- So, doesn't worry about gas/electricity
- Doesn't seem that energy conscience

- has no desperate need to see energy history has a smart heater but doesn't use it/look back on it
- interested in what time/period students need/demand for heat is most used
    - changes yearly
    - If Worcester city council requires them to have a smart thermostat, will install them
        - Always goes after good landlords because they are easier to get

Home presence

Landlord 1

- says university advises students to keep boilers running
    - So they don't freeze

Other landlords:

- say students stay over break so rarely is empty
    - useful

What will motivate to upgrade

Landlord 1:

- if it became the norm, or if a lot of tenants expect it will
- All about providing tenants with utilities they expect
- behavior determined by the level of provisions required of a landlord
- Doesn't want to go over the top, but doesn't want to be shabby
    - Ex. dishwasher talked to Judith and the students said they preferred more storage space
- So basically, will do it if students want it, tenant need determines implementation

All:

- say that if there are good reasons and wants to install new features for heating, will do it
    - but want to see/ask students if it is necessary
    - Say older people 30-40 are not tech savvy

Landlord 3:

- Concern for student properties, lots of freedom with student properties
- Concern that students now have too much have expectations like hotel living
- Supposed to be a transition to the real world, says real world is not like this
- University experience should be learning curve/experience
- This landlord says students use to do a lot more (mow grass) but not allowed to do a lot of things now
    - Willingly provide what they need to

- Concerns over how students will deal with more responsibility for heating

Student pad

- Only 1 landlord uses student pad
- Other 2 do not

Landlord 1

- has no real issues with student pad
- University classed as managing agency, so need to have the university as a proxy

Other 2

- do not even use it students email question about property and u respond back
- Say they do not want direct communication with students, which is prob the big problem
- The most efficient way is through the university
- Student pad is by renting rooms
- not use it because never had a problem getting tenants
- Not the best system
- Give 7 days notice to go around the property
- Seems to be difficult to go through university

What time are homes usually empty/free

All:

- 4 weeks in summer
- With university property, it's about 6-8 weeks of free
- With other non-university housing, let for 11 months, if stay it is easier

Landlord 1

- really difficult bc rental period of 12 months and payment is 11 months
- Starts 1st of July
- Says no one wants it in July
- Some years no one there some there are
- Easy to have a relationship with students, but harder when uni is proxy
- But the university is nice failsafe because does not have to worry about renting it
- So it's a trade-off
- Has gotten better over the years

Closing Remarks

- Double glazed housing
- A cap installed to bill definitely would scare students more to be efficient
- Only can do so much in a cost-effective way

Appendix F: Participant Observation Field Notes

Mapping Student Heating Routines to Demanding Schedules:

An In-Depth Look Through Participant Observation

Steven Lussier Field Notes

Oct. 22

- Students have difficulty turning on their systems, unintuitive.

Oct. 22

- Many have trouble first trying to turn the heat on
- Shows unintuitive system

Oct. 25

- When heat is turned up all the way, constantly, works very well.
    - However, once the heat is turned off, for only a brief period, the temperature drops to an uncomfortable level.

Oct. 25

- Students have issues with non-working heaters. For example, heaters in some bathrooms do not work

Nov. 1

- Many students use the window to regulate heat, with the heater on max, which better reduces

Nov. 1

- Many leave the heat on full and use the window to reduce because it's faster to reduce heat in the room

Nov. 2

- Many do not change the heat when they leave for classes, however, turn the heat either up or down when they go to bed depending on preference

Nov. 5

- Noticed my room stays relatively warm, however, hallway and bathrooms are extremely cold due to lack of radiation and heating systems in these places.
    - The only radiator is in the kitchen which has not been used properly yet

Nov. 7

- Forget to Turn heat down when leaving for the day

Nov. 8

- Notice I am gone for at least 5+ hours every day and am always in an out

    - Makes things difficult when hard to control the TRV

Nov. 9

- Need to open window occasionally for fresh air, and the room begins to smell

Nov. 10

- Roommates left for the week due to their reading week, and when asked what they did with heat they said they turned it on half.
    - Did not want to turn fully off because did not want the room to be cold when coming back. However, shows they care enough not to leave the heat on full

Nov. 12

- Days in the 50s I kept my window open to allow fresh air and temperature regulation

Nov. 13

- My roommates are always in and out constantly, and when asked how they leave their heaters, they say that they always leave them on full due to they work Best on that temperature

Nov. 13

- The main common room, the kitchen, has arguments over what the setting heater should be at and whether the windows should be open.
    - This was a common occurrence, however, a large argument occurred on this day

Nov. 14

- Noticed a genuine lack of user control with the heating in student accommodation.
    - While TRVs are in place, they do not work as intended and do not correlate well to the temperature in the room.

Nov.15

- Hard to determine and control the temperature in the room with no interface
    - Leads to lack of heating concern for students
        - Does not help with sporadic appearances and disappearances due to schedule demands

Nov. 16

- The roommate said many people just put on/ take off layers when getting too hot or too cold
    - Said no air conditioning because summer does not get hot enough
    - Said heating is less of a worry because of winters not too cold, doesn't fluctuate as much

Nov. 17

- Noticed Thermostat does not get that warm even with max level, so I find it easier to leave the TRV always on max.
    - Sometimes the room is way too warm and other times room is way too cold
        - Needs to be addressed

Maxwell Westwater Field Notes

Oct. 22

- No form of thermostat anywhere to adjust besides TRVs
- All the water for the radiators on my side of the flat flows around 2 walls of my room and is exposed, so I can feel if the system is active at all
    - Water in pipes never gets hot

Oct. 26

- Finally noticed intermittent hot water through the pipes in my room
    - Didn't turn on TRV as it wasn't very cold

Oct. 28

- The air started to feel very stale so I opened the windows in just my room, still had the heat off

Oct. 30

- Flatmates had opened the hallway and kitchen windows to air the place out, no idea if the TRVs were on
    - Attempted to turn on the TRV in the bathroom to warm up clothes but there was no response from it

Nov. 2

- Still nothing from the bathroom radiator, even after messing with the TRV more
    - Unclear if the other bathroom's works
- Kitchen started to smell like feet, opened all windows without caring about if the heat was on to air it out, did shut the door to the kitchen

Nov. 5

- Actually cold in my room, turned TRV to full blast but didn't get much
- The pipes only have hot water in them some of the time
    - Very annoying for when you need heat because they don't seem to have a logical timing or demand related to if there's hot water

Nov. 8

- Still struggling with the TRV not being a good control of temperature
- The lack of constant hot water makes the TRV slow and inconsistent to respond
    - This makes it so the temperature isn't regulated very efficiently, basically a Boolean

Nov. 10

- Had a headache and the air was super stuffy and smelled weird
    - Due to this I opened the windows and left my TRV on to air out, knowing that the TRV would take a while to respond I could probably have the place aired out and the windows shut again by then

Nov. 12

- Kitchen smelled terrible

- Opened a couple windows and took out the trash, thankfully wasn't super cold out

Nov. 16

- It's been very warm outside so most of the windows are always left open in the common spaces
    - Mine is open in the day and closed at night in case it gets slightly colder

Megan Pinette Field Notes

Oct. 22

- It is extremely cold in my room and I can not figure out how to turn on the heater.
    - I wore a sweatshirt to bed with my hood on because I was so cold

Oct. 23

- I have been trying to figure out the heater for the past few days trying all combinations to get it to turn on.

Oct. 24

- Still no luck with the heater. I have been using two blankets and sleeping in a sweatshirt

Oct. 26

- I finally figured out how to turn on the heater. I put it on very high because I had been so cold for the past week

Oct. 27

- It is hard to regulate heat
    - either it is too hot or too cold

Oct. 28

- Even if the heat is blasting in my room, no heat gets to the bathroom and it is always freezing

Nov. 4

- Someone made very strong-smelling soup and my room needed some fresh air so I opened my window

Nov. 5

- I accidentally left my heat blasting when I left and my room was very hot when I got back

Nov. 6

- There is a significant heat difference between the hallway and my room

Nov. 10

- I noticed that the kitchen window consistently stays open but it is still hot in the room

Nov. 11

- One of the other WPI students still can not figure out how to turn her heating on. She thinks that the individual TRV in her room may be broken
    - She bought a blanket to keep warm when she is in her room.

Nov. 14

- The heat is completely off but it is still very hot in my room, but I have kept my windows closed

Nov. 15

- It was still very hot and so I opened my window

Nov. 16

- The kitchen window is still open and today it is cold in there, probably because no one had used the stove recently.

Noah Donald Field Notes

Nov. 4

- Window to the kitchen left open again. Very cold in the room, but the radiator wasn't on.
    - Still probably not good for heat

Nov. 5

- Shut off the radiator when I left for our meeting. Came back to a very cold room.
- Will need to set the radiator to low instead.

Nov. 6

- Tried switching radiator to low when I left.
    - Still comfortable, but spent less time away, and the day was about the same temp.
    - Will need further tries to see the difference

Nov. 8

- Left heat on low. Too cold to sleep by the time I was ready to go to bed.
    - Need to remember to set heat higher when I come home.

Nov. 13

- Haven't had to change my heat off low since Thursday. Even still, I don't think the dial is analog.
- It seems that the radiator is either on or off, with the threshold being around 3 or 4.

Nov. 14

- It was nice this morning. I was able to shut off the heat and open the window.
- This was very fortunate, as the air has been really stuffy in my room for a while now.

Nov. 15

- Roommates left the window open in the kitchen again.
    - This has been happening over the course of the time here, but it was especially cold in the kitchen this time because of it.

Nov. 16

- Left the heat on low again before I left to go to the meeting. It’s been getting colder, so
    - I’m hoping this strategy still works out. If so, it should be easy enough to manage heat.

Appendix G: Data Analysis Software Scripts

Available on GitHub at: https://github.com/Max5254/Energize-Worcester-B18

Appendix H: Student Population Survey Flyer

#ENERGIZEWORCESTER

University of Worcester

SCAN ME

bit.ly/energizeWoo

WANT TO BE A PART OF A SUSTAINABILITY RESEARCH STUDY? PLEASE TAKE THIS SHORT SURVEY AND HELP OUT THE ENERGIZE WORCESTER TEAM!

WORCESTER Bosch Group

WPI