Abstract

The Energize Worcester project focuses on identifying student behaviors and perceptions of their behavior about residential heating in order to affect positive change in the realm of home energy usage. Our team analyzed heating data as well as past surveys and focus groups to identify clear areas where students could improve heating efficiency. With the help of the Worcester Bosch Group and the University of Worcester, our team developed recommendations for a campaign to change student behaviors in Worcester, England.

Acknowledgements

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Executive Summary

In 2016, the domestic sector, which includes housing and businesses, accounted for 29% of the UK's total energy consumption (Department for Business, Energy & Industrial Strategy, 2017.a.). In comparison, the service and industry sectors combined use approximately the same amount of energy, revealing a critical issue for the energy efficiency of UK homes. In order to combat this issue, the University of Worcester has begun to adopt a number of policies targeting the improvement of sustainability and sustainable practices with it's own buildings and with it's students. As the student population of the University of Worcester has been growing steadily in the past few years, many students look for off-campus housing in the area. Most students choose to live in homes of multiple occupancy otherwise known as HMOs.

The University of Worcester in conjunction with the Worcester Bosch Group started the Energize Worcester project to investigate the thermal efficiency of HMOs. Five HMOs in the University of Worcester area were chosen to receive a brand new boiler, Worcester Bosch Wave smart heating control system and a heating data logging system. This was done to explore students habits and behaviors in utilizing the smart heating systems to reduce energy usage. In investigating this, a number of main questions were asked:

- What do students know about sustainability and do they behave in sustainable ways?
- What motivations and barriers do students face when trying to live more sustainably?
- How do students living in HMOs utilize smart heating systems?
- Do smart heating systems allow students to live more sustainably?

Methodology:

In order to answer these questions, the following goals were set:

- Evaluate knowledge of students regarding sustainability and sustainable practices.
- Evaluate use of Wave heating systems in student HMOs

In order to complete the first goal, our group held two focus groups to learn more about what students at the University of Worcester thought about sustainability. Along with the focus groups, our group collected free lists from students at the University. The results of the free lists, focus groups and past survey data were all compared to evaluate how educated the students were in regards to sustainability and sustainable practices.

When evaluating the use of the Wave smart heating system, Our group developed and created a program to read, organize and analyze this data. The program produced plots of daily usage data, averages per HMO and per day across all five HMOs. The variable values that were displayed on these plots could then be used to infer if students are using their heating systems with energy saving practices in mind.

Findings

When our group completed our project objectives, a number of observations were made. The implementation of our data analysis program, analysis of previous survey data, free lists and focus groups produced the following results.

1.) **For the majority of the HMOs investigated, energy use is constant throughout the entire day.** After executing our program and plotting the Wave heating data, our team found that four out of the five HMOs have their heating on for the entire day. This was found for all three types of analyses performed.
2.) The students participating in our study

Conclusions/Recommendations

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1. Introduction

As a result of high CO_2 emissions and heating waste, energy conservation has been a critical issue in the United Kingdom in the past few years. In addition to its classically cold and overcast weather, the UK has some of the least energy efficient housing in Western Europe, with residential heating contributing about 18% of the UK's total CO_2 emissions per year (Department for Business, Energy & Industrial Strategy, 2017). Despite the large amounts of energy used for heating, many people still feel uncomfortably cold in their own homes. This problem is especially widespread among students living in houses in multiple occupation (HMOs). When the National Union of Students surveyed individuals living in HMOs, 52% felt too cold in their home, and 48% felt as though their home was "poorly insulated and/or draughty" (National Students Union, 2014).

In recent years, the University of Worcester has needed to increase housing available to a growing student population. In the expansion of accommodations, the University worked with landlords in the area to convert flats into HMOs for their students. Within these HMOs, miscommunication between students and landlords causes excessive heating. Many students are unaware of how much energy they use and do not feel responsible for managing their heat efficiently. The University of Worcester, determined to increase student comfort and the energy efficiency of their housing, initiated the Energize Worcester project.

Created by the University of Worcester in partnership with Worcester Bosch, Energize Worcester aims to find a way to reduce heating costs while allowing students to feel comfortable in their homes. The original focus of Energize Worcester was discovering student perceptions and habits regarding energy usage in HMOs. More recently, the initiative has sought to evaluate the usefulness of new smart heating controls such as the Worcester Bosch Wave.

WPI IQP teams have been involved in this project in the past few years, interviewing students and landlords to learn about their perceptions and habits surrounding energy management and smart heating technology. Previous research teams found considerable inconsistencies in the perceived and actual use of smart boilers and that the motivation of students to learn to manage their heating systems are low (McAteer, et al., 2017).

Our project team built off of this previous work by investigating how students currently manage their heating and their perceptions of being sustainable and energy conscious. Through analyzing past surveys and data from the Wave, we were able to look at the relationship between student's perceptions of their energy management and how they actually manage their energy. Additionally, we also collected data on how students are motivated to be sustainable and what challenges are associated with sustainability. Both analysis of previous work and new data helped us understand student's behavior and develop recommendations to create a campaign aimed at students to engage in more energy conscious behaviors.

2. Background

This chapter will introduce the issues of energy waste in the United Kingdom and the sustainability efforts taken up by the University of Worcester to address this problem. Additionally, the dangers of poor living conditions and how this relates to student accommodations will be discussed. Energize Worcester seeks to address both energy waste and non ideal living conditions within student housing. With the help of Worcester Bosch, implementing smart heating controls such as the Wave could help both issues. Due to our group's focus of creating a campaign to improve student sustainability, this chapter will also detail information on changing student behaviors.

2.1. Energy Consumption and Carbon Emissions in the UK

This section details the energy consumed in the UK, as well as a breakdown of the amount consumed by the individual sectors. It provides information on the factors that impact energy consumption in the domestic sector. Additionally, the carbon dioxide emission levels in the UK is discussed. The Energize Worcester project is directly tied to decreasing carbon emissions through reduction in energy waste.

2.1.1 Energy Consumption

The total amount of energy consumed by the UK has been at a steady decline since the 1990's, with more significant decreases seen since the mid 2000's. This is due to the increase in energy efficient smart technologies used in homes and businesses along with government legislation targeting reducing energy consumption (Office for National Statistics [ONS], 2016). Despite the steady decline over the years, there is still significant room for improvements to be made.

The United Kingdom's energy consumption is broken up into four sectors, transport, domestic, industry, and service. In 2016, the domestic sector consumed 29% of all the UK's energy. The industry and service sectors combined consumed 31% and the transportation sector accounted for 40% of the UK's energy consumption (Department for Business, Energy & Industrial Strategy, 2017.a.). Heating, ventilation, and air conditioning (HVAC) systems made up 62% of energy use in the domestic sector which is approximately 18.6% of the UK's total energy consumption (Cuce, E., 2016).

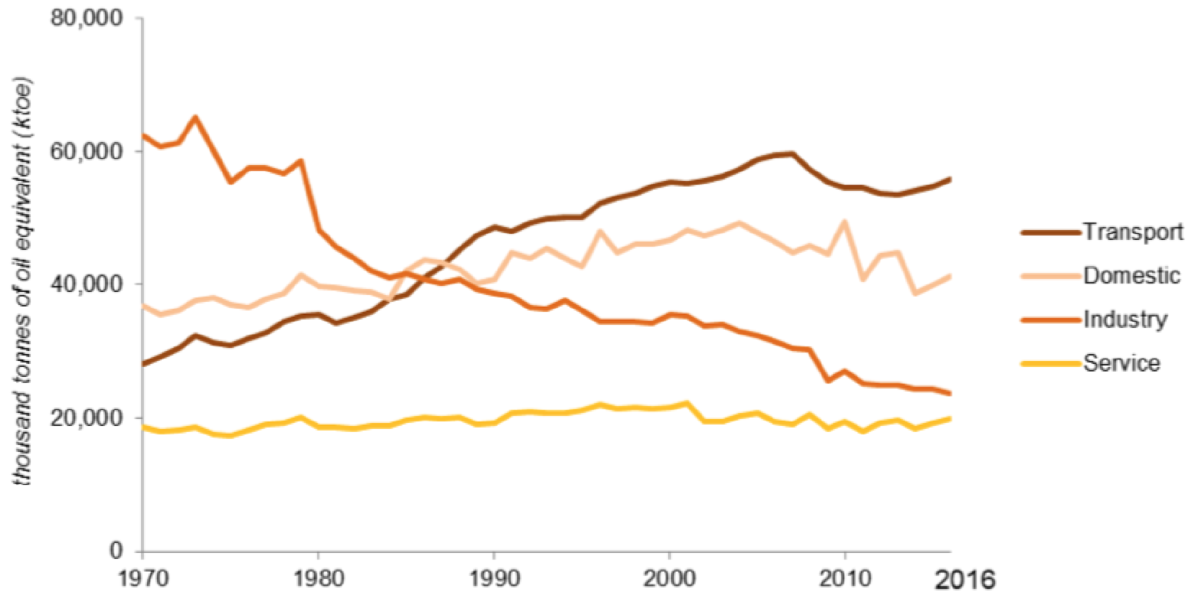


Figure 2.1

Graph of "Final Energy Consumption by Sector"
(Department for Business, Energy & Industrial Strategy. (2017a).)

Figure 1 shows the trend of energy consumption since 1970, broken down into the four sectors. While the overall energy consumption has been declining, there hasn't been a significant decline in the amount of energy consumed by three out of the four sectors. Even though the UK's population has increased by nearly ten million people since 1970, the two sectors most impacted by this increase (domestic and service) have remained fairly constant (Office of National Statistics, 2017). This implies that energy is being used more efficiently within the UK. The domestic sector, made up of energy consumed by homes and businesses, showed the most substantial increase from 2015 to 2016 by a little over 3%. The three main factors that affect this sector are weather, household characteristics, and efficiency measures (ONS, 2016). In years where there have been colder winters, there has been a general increase in the amount of energy consumed in the domestic sector that year. Ideally, a house with fewer occupants will consume lower amounts of energy. Despite this, the number of houses with multiple occupants per house fell .2% from 2015-2016 and the consumption per household increased by 2.1% (Department for Business, Energy & Industrial Strategy, 2017a).

Along with this, the UK's imported energy levels have increased to a level of around 45%, a high that has not been recorded since the 1970s (ONS, 2016). The rising import levels mean that the UK is paying for energy more than it is producing, making energy savings a major national concern.

2.1.2 Carbon Dioxide Emission

Carbon Dioxide is the most dominant greenhouse gas the United Kingdom emits, it makes up over 81% of all greenhouse gas emissions. In the past few decades, the UK has been dedicated to reducing their greenhouse gas emissions, specifically their levels of CO2 emission. To achieve this, they are focusing on lowering their energy consumption. Since 1990 the UK has decreased their overall CO2 emission by 42% with a significant decrease of 6% from 2015 to 2016. A major contributing factor to the continuous reduction of CO2 emissions is the reduced amount of coal being used to generate electricity (Department for Business, Energy & Industrial Strategy, 2017b).

According to the UK's Department for Business, Energy and Industrial Strategy, "30% of CO2 emissions were from the energy supply sector, 32% from transport, 16% from business, and 18% from the domestic sector" (Department for Business, Energy & Industrial Strategy, 2017b). While the overall CO2 levels dropped from 2015 to 2016, the level of CO2 emission from the domestic sector increased by about 5% (Department for Business, Energy & Industrial Strategy, 2017b). This is likely due to the fact that the housing in the UK is relatively old compared to most other European countries. The homes are poorly insulated making it harder and more expensive for the occupants to keep their homes at a comfortable temperature in the colder months. Resulting in an inefficient use of their heating system, and unnecessary production of CO2 emissions (Carrington, 2013).

2.2 Legislation and Government Initiatives

This section discusses three pieces of legislation and government initiatives that have the goal of promoting energy conservation and reducing carbon dioxide emissions. The first piece of legislation, the Climate change act, is aimed at lowering carbon dioxide emissions. The Green Deal, the second government initiative, is designed to encourage home and business owners to make energy efficient improvements to their homes. The third and final government initiative discussed is the smart meter program. The goal of this program is to give homeowners more control over their energy consumption. Legislative initiatives are vital to the Energize Worcester project because they directly impact the benefits of being more energy conscious.

2.2.1 2008 Climate Change Act

In November of 2008, the United Kingdom passed the Climate Change Act. The primary goal of the act was to reduce greenhouse gas emissions by 80% from the baseline set in 1990 by the year 2050. The Climate Change Act also created a Committee on Climate Change, which is in charge of advising and making recommendations to the UK's government on the progress made towards their 2050 goal (Climate Change Act, 2008). In addition to the 2050 deadline, the Climate Change Act outlines carbon budgets as a guide to meet their goal for 2050. A carbon budget is "a cap on the amount of greenhouse gases emitted by the UK over a five-year period" (Committee on Climate Change, n.d.). In 2013 the UK met their first carbon budget and is on track to meet their second, but according to the Committee on Climate Change, they do not expect to meet the third or fourth unless they can "increase the pace of emission reduction" (Committee on Climate Change, 2013).

2.2.2 2012 Green Deal

To further their commitment to reducing greenhouse gas emissions and energy conservation, the UK implemented the Green Deal in 2012 (The Green Deal, 2012). Its purpose was to promote energy efficiency improvements in the UK by helping home and business owners "implement more green technologies in their properties" (Green Deal Initiative, n.d.b). The idea behind the Green Deal is that if home and business owners install the new green technology in their homes, they will not have any upfront costs. Instead, they will get a long-term loan from the government to pay for the improvements and pay back the cost of the improvements through their energy bill (Green Deal Initiative, n.d.a). The most common efficiency improvements added to homes and businesses are insulation, new heating system, draught-proofing, installing double glazed windows, and adding renewable energy systems (Gov.UK, n.d.a). By March 2014, there were approximately 600,000 business and homeowners who took advantage of the Green Deal and had energy efficient improvements made and installed on their property (Department of Energy and Climate Change, 2014a).

The Green Deal has the potential to be beneficial and improve the comfort of the students living in HMOs. However, there have been few landlords who have taken advantage of the Green Deal. Many landlords believe that the Green Deal and similar government initiatives are not worth the time it takes to make all the renovations and installations. Furthermore, if the landlords want to get a tax cut for the improvements, the HMOs must only have student tenants, which often is not the case (Braconnier, 2016). Student or tenants living in HMOs have the option to request that their landlord make energy efficient improvements in their home. However, it is often not worth it for the tenants because if the requests are approved, the landlord would not be responsible for any financing of the improvements. In addition, once the installations are made they are typically considered fixtures of the property and thus become the landlord's property, preventing the tenants from removing any improvements they made when they move out (Department of Energy and Climate Change, 2016).

2.2.3 Smart Meter Program

The Smart meter program is aimed to install “smart electric and gas meters in all domestic properties and smart or advanced meters to smaller non – domestic sites” in the UK by 2020 (DECC, 2014a). Homeowners who choose to install smart meters into their home will not be “charged separately for the smart meter or for the In-Home display” (Gov.UK, n.d.b). The cost of the smart meter and its maintenance is currently paid for in the homeowners energy bill, and that will not be changing (Gov.UK, n.d.b). By having smart meters in their homes, homeowners will be able to manage their energy consumption and lower their carbon footprint. They will have more control of their energy bills and save money in the process. Smart meters can provide data and information to the energy networks, which is a crucial step towards the UK's shift towards implementing smart grids (DECC, 2014a).

The UK is in the process of implementing smart grids for their electricity network. The European Technology platform defines the smart grid as, "an electricity network that can intelligently integrate the actions of all users connected to it—generators, consumers and those that do both—to efficiently deliver sustainable, economic and secure electricity supplies" (Jenkins, Long, Wu, 2015). Smart grids will support the UK's carbon reduction efforts and create a more affordable and secure energy system (Department of Energy and Climate Change, 2014b). It will also be easier to integrate other green technologies such as solar and wind power sources once the smart grids are implemented (Smart Energy GB, n.d.).

2.3. Sustainability Efforts

This section describes some of the efforts of the University of Worcester sustainability goals and targets. Sustainability is crucial to the UK's goal of reducing carbon emissions and energy consumption. The University of Worcester is one of the most environmentally conscious Universities in the United Kingdom. Every year they strive to improve their energy impact as well as lower their carbon dioxide emissions. They not only focus on their campus but on changing their student's behaviors and attitudes towards energy efficiency.

2.3.1 University of Worcester

Along with the United Kingdom's sustainability efforts, the University of Worcester is dedicated to achieving their own goals. They have a sustainability committee which includes both student and faculty members. The committee works to "develop local, regional, national, and international networks to further the sustainability agenda" (University of Worcester, 2018). The University of Worcester is ranked in the top four greenest universities in the United Kingdom (University of Worcester, 2017.b.). A major part of their efforts comes from the Environmental Management System (EMS) that they implemented on their campus in 2007. The EMS "provides a framework for managing their environmental responsibilities efficiently in a way that is integrated into all of their operations" (University of Worcester, 2017.b.). The University also creates annual sustainability targets for energy, water, waste management, emissions and discharges, sustainable procurement, transportation, health and wellbeing and construction and refurbishment (University of Worcester, 2017.g.).

The University of Worcester has set strict carbon emission targets for themselves. They want to reduce their emissions by 40% of their 2008-2009 levels by 2020 (University of Worcester, 2017a). Since 2012-2013 they have exceeded the yearly reduction rate they set for themselves despite a consistently increasing student population. They saw the most significant reduction in 2015-2016 when their emissions decreased by 12% in that year and 32% overall since their 2008-2009 baseline (University of Worcester, 2017a). In addition to being dedicated to reducing their CO_2 emissions, lowering energy consumption is a top priority for the university. In 2015-2016 their goal was to consume 6% less gas and 6% less electricity from the previous year (University of Worcester, 2017.c.).

The University not only focuses on their energy consumption but on their student's as well. They try to change their student's behaviors to be more energy efficient to help decrease the University's overall energy consumption. The Student Switch Off campaign is an annual competition that offers incentives for students to be more energy efficient. They track the total energy savings amongst all the residence halls, and at the end of the year, the residence hall that saved the most energy gets a reward (University of Worcester, 2017.c.).

2.4. Student Accommodations

The University of Worcester's student population has expanded significantly in the past few decades. As of the 2016-2017 school year, the University had a total of 10,747 students enrolled (University of Worcester, 2017.d.). Despite having such a large student population, the University has only 1,000 rooms available for on-campus accommodation (University of Worcester, 2017.e.). Due to this disparity in available accommodations, nearly

90% of students must live off campus. Living in off-campus housing brings forth many challenges for students and complicates the sustainability efforts of the University.

2.4.1 HMOs

Many students turn to private rented properties in lieu of on-campus housing, living in Houses in Multiple Occupation (HMOs). HMOs are officially defined as "...a house or flat in which three or more persons forming two or more households share one or more basic amenities such as a bathroom, toilet and/or kitchen facilities." (Worcester City Council, 2017). As of January of 2018, there are a total of 761 HMOs in the city of Worcester, providing housing for 4,105 residents (Worcester City Council, 2018). HMOs are highly regulated, through requirements for certain standards of conditions as well as through a cap on the amount of HMOs allowed in an area (Worcester City Council, 2014). While HMOs are available to anyone, many are geared towards housing students. The University of Worcester have developed an accreditation process which allows landlords to advertise their HMOs through University websites as long as they are up to University standards (University of Worcester, 2009). There are many regulations on the conditions of an HMO, including minimum size requirements, gas and electrical safety regulations, and essential amenities such as a shared kitchen and bathroom.

2.4.2 Heating and Energy Efficiency Requirements

Included in the list of city-mandated standards for HMOs are specific heating and energy efficiency requirements. All HMOs must allow residents to control the temperature of their home, having a wall-mounted heating apparatus such as a radiator valve or thermostat (Worcester City Council, 2017). In addition to providing adjustable heating, the heating system must have the ability to maintain an indoor temperature of twenty-one degrees Celsius when the outdoor temperature reaches negative one degrees Celsius at a reasonable cost (Worcester City Council, 2017). In regards to energy efficiency, HMOs must have a minimum energy performance rating of E (on the scale of A to G), and the landlord must provide tenants with a copy of the energy performance certificate (Worcester City Council, 2017).

2.4.3 Student Living Conditions

Despite having legal regulations in place to protect students living in private housing, conditions are not always optimal. For example, the City of Worcester provides clear requirements for working smoke and carbon monoxide alarms to be installed on every floor of an HMO (Worcester City Council, 2017). However, a study run by the National Union of Students found that only 87% of student accommodations had smoke alarms and 32% had carbon monoxide detectors (National Students Union, 2014). The majority of students participating in the study reported having issues with their house. In relation to heating, 52% of students "felt uncomfortably cold in their home and... 48 per cent felt that their accommodation was poorly insulated and/or draughty," (National Students Union, 2014). In Worcester, many students living in HMOs have similar experiences. The May 2016 IQP team found that 60% of student homes had at least one cold area in their home (Ruiz-Cadalso et al., 2016).

2.4.4 Damp Housing and the Associated Risks

Proper housing conditions are necessary for maintaining a healthy lifestyle. "Many studies have shown a relation between damp housing and health" (Gemmell, 2001). Living in damp or cold housing can lead to serious health risks. The researchers found links between people living in cold conditions and having chronic health issues. While the study could not identify causation, they found a correlation between unideal housing conditions and occupant health. The researchers discovered that living in rented conditions had a significant increase in the prevalence of chronic conditions (Gemmell, 2001). Student renters who cannot access adequate heating are living at elevated risk of health issues.

Another study conducted in Worcester, England found that nine percent of respondents believed they lived in damp housing (Packer, 1994). The researchers concluded that the association met many of the criteria to suggest causality but could not definitively conclude that damp housing causes more illness in adults. A third study conducted in England also set out to discover links between damp housing and adult health. The research was designed to take a quantitative analysis of a qualitative study. The study looked at 8,889 surveys sent to residents of several English towns. A bivariate analysis found an association between dampness and many health conditions. The researchers concluded that cold housing was more detrimental to health, however, due to the similarity of cold and damp housing, they recommended that more studies be conducted to further investigate the link between damp housing and detrimental health (Evans, 2000).

2.5. Smart Heating Controls

As technology progresses, the concept of a smart home has become common knowledge to the general public. A smart home is a home with many internet connected devices that can control anything from lights, music, door locks and heating. There has been a steady rise in the use of smart heating controls such as the Worcester Bosch Wave device. Not only do these devices provide heating control but may also perform data logging and analysis, which can be used to improve energy savings. In this project we will work with Worcester Bosch to better understand how students living in HMOs utilize the wave device.

2.5.1 The Wave

The Worcester Bosch Group has created their own proprietary heating control product called the Wave. This product is designed and sold for single home use. Currently, the wave only has the capability to control one heating zone in a home (Worcester Bosch Group, 2018). This smart thermostat has many functionalities to improve the thermal efficiency and comfort of homes. The Wave is smartphone compatible with the ability to connect with both iOS and Android devices in addition to the touchscreen panel on the system. As long as the system stays connected to the internet, the controls are available to the owner from anywhere with an internet connection (Worcester Bosch Group, 2018).

Up to eight devices can be connected to the Wave system. With this functionality, the Wave also offers the ability to sense when someone is home through their smartphone (Worcester Bosch Group, 2018). The collected data can be used by the system to help create schedules for when the boiler will operate at a lower temperature, saving the user energy and money while they are out of the house (Worcester Bosch Group, 2018). The Wave device stores data locally which contains occupancy times, hot water and energy usage. The Wave is advertised to have a system efficiency upgrade of at least 4% which can mean considerable monetary savings (Worcester Bosch Group, 2018).

2.5.2 Consumer Attitudes

The use of smart heating controls has not been without its fair share of problems. With some customers having a better understanding of their systems than others, many fail to use their systems with maximum savings as a result. One study in the UK found that 70% of smart heating control users felt that the system positively influenced energy savings and their home heating behavior (Dmitrokali et al., 2015). This shows that 30% of people felt that a smart heating control system gave them no energy savings benefit.

There are multiple reasons for the dissatisfaction, but the complexity of the user interface is a main concern. In a report written by the UK's Department of Energy and Climate Change (DECC), consumers found smart heating controls challenging to understand (DECC, 2018). This in part correlates with poor use of the system, leading to failures to meet energy saving goals. As a result, there is a problem with current smart heating controls as for many there is a technological bridge to cross to use the product correctly.

Along with technological barriers, some people are more or less interested in energy savings than others. According to a qualitative study by the UK's Department of Energy and Climate Change, those who used heating controls can be split into numerous groups of user types. The extremes such as "rationers" and "ego-centric" user types would either ignore comfort for savings or ignore savings for comfort respectively (Rubens, S. & Knowles, J. 2013). The personal preferences of users can significantly affect the potential cost savings of the system and therefore their outlook on its usefulness.

2.6. Behavioral Change

One of the greatest challenges that arises from this project is changing students behavior. As useful and game-changing new technology can be, it alone cannot produce a significant reduction in energy waste. Without changing students' behaviors, the misuse and waste of energy will still occur. To create a practical and lasting solution, integrating behavioral change into our intervention is necessary (Chaplin, G, & Wyton, P., 2014).

2.6.1 Models of Conservational Behavioral Change

Behavioral change is a topic that has been thoroughly studied by psychologists for years. One of the most influential models of behavioral change is the Transtheoretical Model of Change proposed by James Prochaska. In this model, Prochaska outlines the six stages of change. These stages include: precontemplation, contemplation, preparation, action, maintenance, and termination (Prochaska, J., & Velicer, W., 1997). Prochaska emphasizes that change is a process that occurs over time, rather than a sudden action. While the stages seem to be linear, people often regress to earlier stages before moving forward (Prochaska, J., & Velicer, W., 1997). Prochaska included many processes of change in his model; however, they are tailored to changing health-related behaviors. For our campaign, it is necessary to understand the process of how students change their behavior. We will use this model to understand student behavioral change.

There have been other studies looking specifically at changing behaviors related to energy conservation (De Young, R. 1993, McMakin, A., Malone, L., & Lundgren, R.. 2002). Many of these studies have determined that educational materials alone are not sufficient to cause a change in behaviors. Instead, the combination of various techniques must be used. In the paper "Changing Behavior and Making It Stick," Raymond De Young offers three types of techniques to alter behavior: informational, positive motivational, and coercive. De Young believed that informational understanding is longest lasting if there is self-discovery or direct experience tied to the knowledge (De Young, R., 1993). Positive motivation draws a person to a behavior due to the benefit it will provide the individual. Coercion applies a sense of duty and regret that convinces a person to perform a behavior (De Young, R., 1993).

In a later study, energy conservation efforts were introduced to military personnel that do not pay for their utilities. The authors found that people focused on how energy conservation benefited them. For example, the reasons people provided for adopting more energy efficient habits were to have a more comfortable home, be a good example for children, and "do the right thing" (McMakin, A., Malone, L., & Lundgren, R.. 2002). Adoption of energy conscious behavior is more likely to occur when the there are clear benefits to the energy conservation and the information provided is shown in a personal and specific way (McMakin, A., Malone, L., & Lundgren, R.. 2002). The authors of the study recommended tailoring energy conservation efforts to the specific populations they target. While the target population of our project do not have to pay for utilities like the population in this study, we suspect some of the motivations for change will be different due to the age group. This case study demonstrates that making behavioral change is possible, but it is essential that the intervention is tailored to the target population.

2.6.2 Engaging Students in Sustainability

There are various behavioral studies that focus on student engagement in sustainability efforts. One study, conducted by Gareth Chaplin and Paul Wyton, discusses the value-action gap that exists with students believing sustainability is important but not engaging in sustainable actions. Educational programs to increase sustainability alone are not enough. Instead, using a combined effort of behavioral change and technological advancement is needed to tackle the value-action gap that students express (Chaplin, G, & Wyton, P., 2014). Of the sample of students they surveyed, around 75% of respondents believed that the responsibility of sustainability lies with organizations, companies, and the government rather than individuals (Chaplin, G, & Wyton, P., 2014). In order to shift this way of thinking, the authors suggest focusing intervention efforts on the impact of individuals on sustainability and how a shift in behaviors can result in practical change. In addition, they also recommend investing in green technology to support behavioral efforts (Chaplin, G, & Wyton, P., 2014). In the Energize Worcester campaign, we will draw heavily from the findings of this study. The subjects being UK university students, we can use the attitudes of students and the researcher's recommendations as a baseline for our own data collection and as an aid to developing our campaign.

2.7. Previous IQP Background

The Energize Worcester IQP has been active since May of 2016. There have been three previous IQP teams in Worcester, England working on the project. This section will summarize their findings to provide a clear idea of previous findings and recommendations provided by other WPI students.

2.7.1 May 2016

The first iteration of the Energize Worcester project focused primarily on landlord and student opinions about heating in HMOs in Worcester England. Their methods included gathering information and diagnosing problems to determine how energy efficient and energy conscious students and landlords were. They concluded that there was a severe disconnect between how energy conscious students are and how energy conscious they believed they were. (Braconnier, et al., 2016) They recommended that groups on campus at the University of Worcester should start programs to better educate students about thermostatic control and overall heating efficiency in their off-campus housing.

2.7.2 May 2017

In May of 2017, another IQP team continued the Energize Worcester project. The group focused on the implications and results of smart heating in student homes. Their idea was that if students had more accessible controls for their heating systems that students would become more invested in their home heating. The group found that there were issues with the implementation of smart heating. Students were unmotivated to change their habits because they did not see any tangible benefits from the behavioral change (White, et al., 2017).

2.7.3 December 2017

The most recent iteration of our project was completed in December 2017. The group focused on the difference between perceived and actual behaviors of the students living off campus. The group was unable to clearly identify factors that caused inconsistent and inefficient usage of the heating systems. In doing their analysis of the heating data, the group discovered that there are a significant amount of inconsistencies. The group recommends that as the project continues to try and increase use of The Wave heating system as well as work towards identifying external factors that could affect heating in student homes in Worcester, England (McAteer, et al., 2017).

3. Methods

The goal of the Energize Worcester project is to create a campaign to engage students in energy sustainable behaviors to reduce heating waste in HMOs. To accomplish this goal, we performed the following:

- Analyzed data collected from previous Energize Worcester projects to find patterns and themes of current student behavior
- Learned of the barriers students encounter when trying to be sustainable and what motivates students to be more sustainable
- Gained more detailed knowledge of student's habits and energy use within the five HMOs fitted with the Wave
- Make recommendations for activities and materials that aim to convince students to adopt more energy conscious behaviors

3.1 Analyzing Data Previously Collected

Over the course of the Energize Worcester project, previous project teams have collected a significant amount of survey and heating data from HMOs at the University of Worcester. This section details our methodology for how we handled and analyzed the different types of existing data.

3.1.1 Analyzing Existing Surveys

With the extensive amount of survey and technical data collected by previous Energize Worcester teams, one of the most important parts of this iteration of the Energize Worcester project is data analysis. Our team took survey data collected by past teams, coded them, and identified behavioral and belief-based trends. We used a total of five surveys conducted in 2016 and 2017. The most relevant being the Spring and Fall 2017 Energize Worcester surveys. We used this survey, as well as three non-Energize Worcester surveys conducted by the University (Student Travel 2016, Student Travel 2017, and Student Union Lifestyle) to determine what attitudes and behaviors students have in regards to sustainability. The Student Travel 2016 and Student Travel 2017 surveys are the same set of questions sent to the general student body two years in a row. The Student

Travel survey looks at general sustainability habits that include recycling, waste, energy, transportation, and opinions about how sustainable the University of Worcester is. The Student Union Lifestyle survey was used to determine student's thoughts and habits regarding various sustainable behaviors. The survey responses were provided to us through the University of Worcester in the form of excel sheets. By analyzing past behaviors, we will be able to determine critical areas to improve the sustainability of students in HMOs.

The analysis of these surveys occurred within the excel sheets that the responses were recorded in. Prior to analyzing the responses we eliminated the survey questions that were not relevant to our project. After narrowing down the questions for each survey, we screened each individual survey response for missing answers, and those that were incomplete were omitted from analysis. For questions that were scored on a scale, whether numbered or descriptive (Strongly Agree to Strongly Disagree), the frequencies of responses for each option on the scale was determined and then compared through graphical representation. For questions that provided more open ended responses, the responses were coded for content and then sorted into major categories. Coding was performed by two team members in parallel and then compared for confirmation. Once answers were sorted into appropriate categories, the frequencies of answers were compared through graphical representation.

To analyze Student Travel 2016 and Student Travel 2017, we divided up the responses by what type of accommodation the student was living in (Student Hall on Campus, Student Hall off Campus, Shared Housing, Private Housing, and Living at home). Once we had the responses broken up into the five different categories we analyzed them as mentioned above. Once our analysis was complete we decided to omit the responses we had for the students who were living at home because it was outside the scope of our project and it had an extremely small sample size. We also omitted the Shared Housing category due to its similarly small sample size. As part of our analysis, we compared the results from both the 2016 and 2017 versions of the survey to determine if there had been changes from one year to the next.

3.1.2 Analyzing Existing Worcester Bosch Heating Data

In order to analyze the massive amount of data collected by the Wave system, our team developed software to identify and analyze important metrics within the data. With our developed software, we were better able to visualize heating trends using the information collected by the Wave systems installed in student homes. By expanding the scope of the software, we explored the hard data collected and used that as a part of our data triangulation to identify trends in the data collected.

Our developed software reads relevant metrics collected by the Wave system and graphs them to better visualize the data. Currently, there are over 3 million points of data collected by the Wave systems installed in student HMOs. The goal of our data analysis was to draw trends using various sampling techniques of the data. We took the existing data and the data that is still being collected and graphed it against different collected metrics to identify trends in the data. The Wave system currently collects:

- Primary Temperature
- Primary Temperature Setpoint
- Hot Water Outlet Temperature
- Hot Water Temperature Setpoint
- Central Heating Active
- Hot Water Active
- Actual Power

Due to the large amount of data recorded by the Wave, we have worked to synthesize down the massive amount of collected data. We synthesized the data down from the millions of points that Worcester Bosch has collected in order to better understand overall trends in student behavior. Using code developed by our team, we have graphed the data in various ways to discover trends in the data allowing us to compare our results to the analyzed survey data. This allowed us to find points of disconnect between student beliefs and behaviors. One metric we used was to synthesize the data "across time", meaning we looked at every day at every point and collected data across several days to properly identify average values for that time slot. We took that data and sampled it further in order to more clearly represent the data our goal was to reduce the number of points being graphed by a factor of at least 25 taking our samples from 8300 points per graph down to a more manageable 332 points per graph. We found that systematic sampling gave us the best representation of the data while not reducing the data too much. This allowed us to more easily look at the data across the times to understand on a broader scale what the millions of data points which allowed us to more accurately provide recommendations for future campaigns.

Our program was written using Python 3.6.4, the OS, Numpy, Matplotlib, Statistics, CSV, and XLRD python packages. The program has several functionalities that allow it to analyze large or small amounts of collected spreadsheets from the Worcester Bosch Wave systems. The program operates by reading a calculated amount of spreadsheets following specific categories. The program is able to read all of the data, all of the data from a specific house, all of the days that every Wave system has recorded, or a specific data from a specific file. WIth the ability to look at specific days we were able to better identify trends in houses as well as overall trends from the students in the five houses that Worcester Bosch currently collects data from. The program can analyze the data in a number of ways including averaging numerous days together, calculating standard deviations across time on a set of given days, this has given us many different avenues to explore the collected data to better understand trends in how the students use their heating systems. The goal of the software is to The graphical representations of the data allowed our team to visually see whether or not students acted in accordance with how they reported they act in regards to heating behaviors.

3.2 Collecting Information Regarding Student Motivations in Engaging Sustainability

In addition to the data collected by previous Energize Worcester groups, we collected data regarding how students feel about sustainable behaviors and what challenges and motivations they experience when trying to be more energy conscious. This qualitative information supports the quantitative data collected through the Wave and past surveys. This information provides insight into how students can be motivated to conserve energy. Data collection consisted of two parts: free listing and focus groups. Free listing provided us with baseline information to develop questions for our focus group. The focus groups provided us with detailed information on students' perceptions about being sustainable and what it would take for them to participate in behaviors that are more sustainable. We chose free listing and focus groups as methods of data collection due to their ability to gain substantial amounts of data within a short amount of time.

3.2.1 Free Listing

Free listing is a tool that provides a researcher with knowledge about what is within an area of interest and the relationships between objects in that area (Gravelee, 1998). Previous data collection in this project has discovered a lot of information about how students understand and use the heating controls in their homes. To recommend an effective campaign, we must also learn how students view energy conservation and their perceptions of the relationship between heating and sustainability. Free listing can be a powerful tool when trying to gain context for further research. As described by Bernard, "free listing can be used to find out where to concentrate effort in applied research, and especially in rapid assessment" (Bernard, 2018, p. 238). It is important to note that free listing data alone should not be relied on, its purpose is to provide a foundation for further studies. In our project, we used the data gathered from free listing to guide questions for focus groups.

The free listing activities were done using paper and pen, with the prompts provided on a sheet of paper that students may write upon. Prior to the activity, volunteers were provided with an informed consent form to read and sign. After finishing the free listing, we asked necessary demographic information of the volunteer, such as age, year in school, and whether they live on or off campus. The target population was the general student body of the University of Worcester, and participants were recruited through asking students in residence halls, the Hive, and through asking students in societies. We chose to use the general student body as our target population, instead of students specifically living in HMOs, due to the open nature of the information we wanted to obtain. It is not expected to be a significant difference in the perceptions of students living in HMO's with the Wave installed and the rest of the student body. Our sample size was 25 participants. Free listing prompts consisted of statements such as, "Please list why saving energy is important, and what are the reasons to save energy?" The full list of questions is provided in Appendix D. To reduce the time spent by respondents on this activity, each respondent was provided with two of the three prompts. We gave participants different prompt combinations in a partially random way, making sure each prompt had the same amount of responses. When provided with the prompts, students were asked to write down all of the words and phrases that come to mind.

Once the data was collected, responses were cleaned up and entered into an excel sheet. Cleaning up refers to the condensing of synonyms or misspellings of words to become one unique item (Bernard, 2018). After data was cleaned up and entered into a spreadsheet, various analyses were performed. We first determined item frequencies and list order standardized to list length. These determinations can provided us will information on how important, or salient, specific items are (Bernard, 2018). The average distance between items were also determined; this provides us with the information about how related two items are. Depending on whether items cluster or have a significant distance from each other can show whether people associate the items with one another (Gravelee, 1998). Distance can be determined pairwise or through the creation of item matrices. Within these matrices, the distance between items is scored from 0 to 100, with 0 meaning they are the same item and 100 being there is the maximum distance between the items. We used a free list analysis software, FLAME, to perform these analyses. After completing our analysis, we selected items and relationships between items to be explored in our focus groups. We made selections through frequency and order analysis using a screen plot, as well as through content analysis for relevance.

3.2.2 Focus Groups

After we identified items and relationships of interest, we determined that further research must be done to verify the results of the free lists and to develop topics to recommend for our campaign. Our focus groups involved a discussion between groups of volunteers moderated by two members of our team. Focus groups allowed us to gain detailed information on specific topics from a variety of viewpoints. One of the unique strengths of a focus group is the way volunteers interact when asked questions. Participants tend to build off of each other's responses, and new topics and opinions may arise that would otherwise not have (Leung & Savithiri 2009). There are limitations associated with focus groups. It is very easy for discussions to be derailed unless the moderator can properly keep participants on track.

Our group performed two focus groups that consisted of student volunteers that were recruited and provided with the informed consent from. The head of the Student Union aided us in recruitment of volunteers through emailing various student organizations on campus. Students interested in participating were given a Google Form to provide their contact information. We then contacted these students to set up a meeting time and held the focus group on St. John's campus. Additionally, we asked students who we were living in the residence halls with to participate in another focus group. The sessions were held on the universities St. John's Campus and recorded via iphone for later analysis. The questions asked involved how students are motivated to be sustainable and the reasons why a student would not participate in energy-conscious behaviors. Some examples of questions include "What are sustainable behaviors?" and "Who is responsible for sustainability?" A full list of focus group questions can be found in Appendix F. During the focus group, one project member was taking notes on the discussions, while another member of our team was facilitating the conversation. After the focus groups were conducted, our group transcribed relevant parts of the recordings. The data collected was analyzed using content analysis. Responses were coded to establish themes and topics to recommend for our campaign. We also performed frequency analysis which will be represented graphically.

3.3 Performing Follow-Up Surveys

To further assess how the students in HMOs view sustainability and use their heating systems, we conducted a survey that was originally performed in the Spring 2017 Energize project. This information was collected through online and in-person surveys which were given to the students living in the five HMOs that have the Wave system installed. The survey that we administered had the same set of questions as the survey used by the Spring 2017 Energize Worcester project team. By using the same questions, we are able to obtain results that are comparable to those from the previous year. The full length survey can be found in Appendix F. The information gathered was analyzed in the same way as the past survey data. Responses were provided via Excel sheet and analysis was also done via Excel.

4. Findings

In this section, we discuss the attitudes and reported behaviors of students that were determined through analysis of survey, free listing, and focus group data. Additionally, we discuss the results obtained from analysis of the WB data from the HMOs fitted with the Wave.

4.1 Student Attitudes and Reported Behaviors

Through our surveys, free listings, and focus groups, we have generated data on student perceptions and reported habits relating to sustainability, helping the environment, and energy and heating usage. In this section, we describe the results and the implications of these data as it relates to our efforts to change student behaviors.

4.1.1 Findings from Past Survey Data

The Student Travel Survey was administered to students in both 2016 and 2017. It consisted of 36 questions that asked about students travel habits, what their most common form of transportation is, what sustainability programs they have been involved in, and what their sustainability habits are. The 2016 survey received a total of 1214 responses and the 2017 survey received a total of 271 responses. The questions that we chose to analyze focused on the students knowledge and habits regarding sustainability. Specifically we looked at the follow questions in both surveys:

- Do you have any of the following at your current student residence: Programmable thermostat e.g . (sets the time and temperature of your boiler) and/or Light motion sensors
- During the last semester, how often did you: Turn of lights when leaving a room, Switch off electrical appliances when not in use, Set thermostat to 18 degrees or lower during cool or cold weather

The graphs below show the responses from the 2016 student travel survey compared to the responses from the 2017 student travel survey. The results shown in graphs 4.1 through 4.4 are responses to the aforementioned questions. Graphs 4.1 and 4.3 represent the responses from students living on campus and in rented housing respectively, to the question “Do you have any of the following at your current student residence: Programmable thermostat e.g . (sets the time and temperature of your boiler) and/or Light motion sensors”. The vertical axis is the percent of students and the horizontal axis is the response options. Figures 4.2 and 4.4 represents the students responses to the question “During the last semester, how often did you: Turn of lights when leaving a room, Switch off electrical appliances when not in use, Set thermostat to 18 degrees celsius or lower during cool or cold weather.” The vertical axis is the percentage of students who answered a certain way, and the horizontal axis are the response options. Responses from 2017 are displayed on the left side of the graph and the responses from 2016 are displayed on the right.

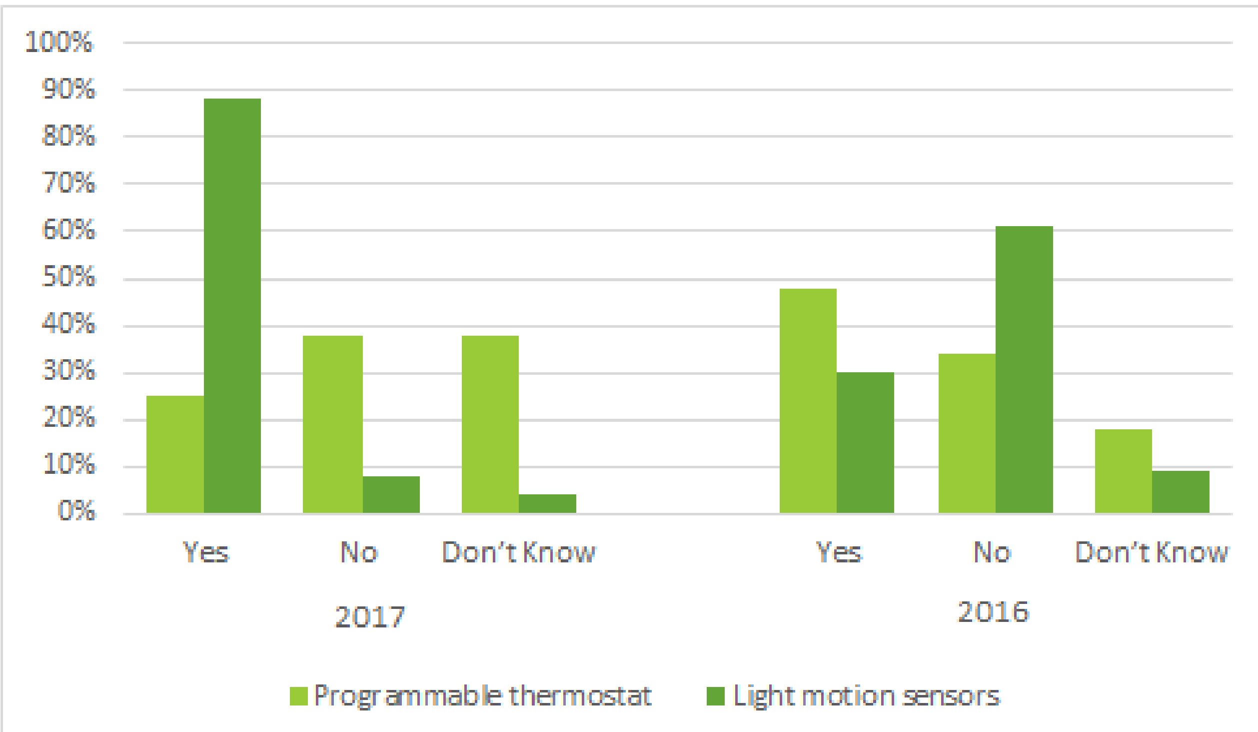


Figure 4.1

On-campus student responses to the questions “Do you have any of the following at your current student residence: Programmable thermostat e.g . (sets the time and temperature of your boiler) and/or Light motion sensors”.

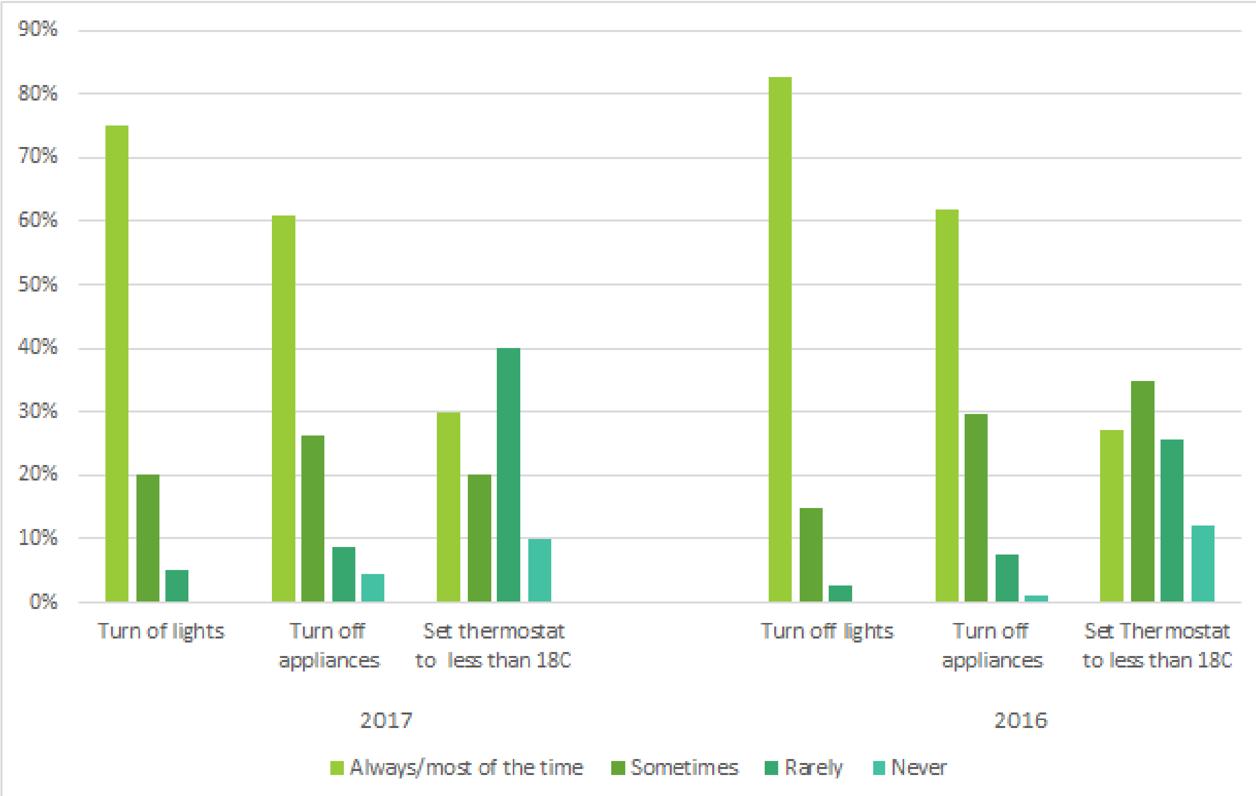


Figure 4.2

On-campus student responses to the question: "During the last semester, how often did you: Turn of lights when leaving a room, Switch off electrical appliances when not in use, Set thermostat to 18 degrees celsius or lower during cool or cold weather."

As show in Figures 4.1 and 4.2 above, for students who live in residence halls located on the University of Worcester's campus, the trends in the answers for both the 2016 and 2017 surveys were fairly consistent. The main difference in these data being the amount of students who set their thermostats to less than 18 degrees celsius. From 2016 to 2017 there is a slight increase of 5% in the number of students who say they always or most of the time adjust their thermostat. However, there seems to be a shift from the number of students who said they sometimes set their their thermostat to less than 18 degrees celsius in 2016 to a significant spike in students who said they rarely set their thermostat to less than 18 degrees celsius in 2017. There is also a decrease, about 20%, in the amount of students who said that they have a programmable thermostat in their Halls on campus from 2016 to 2017, shown in figure 4.1. Using this information we are able to infer that the students in 2017 who have programmable thermostats are more actively interacting with their thermostats. It is important to note that the residence halls on campus do not have programmable thermostats, to best of our knowledge. Therefore the the students who responded to this survey saying that they had access to a programmable thermostat were most likely referring to the radiator controls that they have access to.

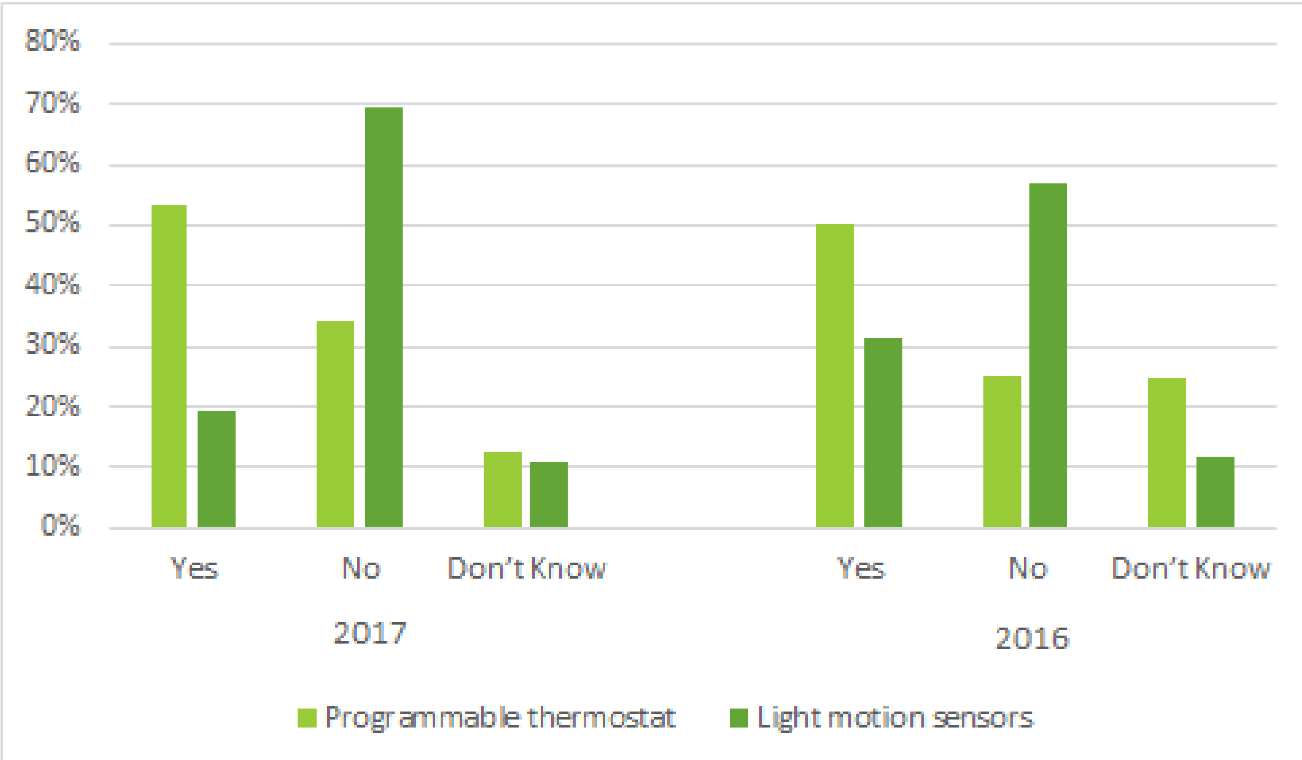


Figure 4.3
Private accommodation student responses to the question: "Do you have any of the following at your current student residence: Programmable thermostat e.g . (sets the time and temperature of your boiler) and/or Light motion sensors".

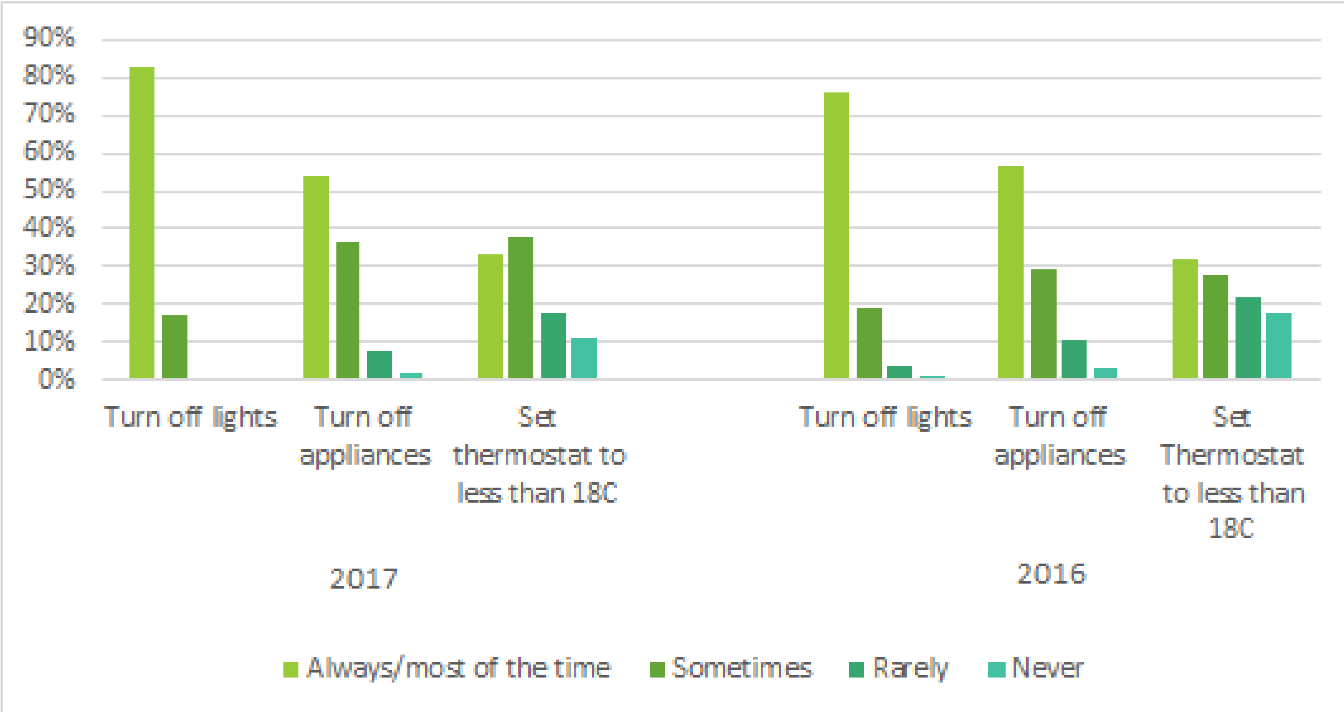


Figure 4.4

Private accommodation student responses to the question: "During the last semester, how often did you: Turn of lights when leaving a room, Switch off electrical appliances when not in use, Set thermostat to 18 degrees celsius or lower during cool or cold weather."

As shown above in Figures 4.3 and 4.4, for students who rent their own accommodations, there was an increase from 76% to 83% in students who claim that they always or most of the time turn off lights when they leave a room. This action appears to be a conscious decision, as only 30-40% of people in both 2016 and 2017 have light motion sensors installed in their homes. A smaller portion of students, about 55%, responded that they always or most of the time turn off their appliances when not in use. In regards to setting the thermostat below 18C, the responses are much more varied. In 2016, around 40% of students said that they rarely or never set their thermostat less than 18C.

When comparing the results from 2016 and 2017, there are very little differences in the turning off lights and turning off appliances categories. There is a slight change in the thermostat category, with 10% of students shifting from rarely or never to always/most of the time and sometimes.

In general, the students living on campus are freshmen or first years and the students living in private residences off campus are upperclassmen or second and third years. We chose to compare the students who live off campus in their own private accomodations to the students who live in residence halls on campus in 2017. This comparison allows us to see how students change their behavior as they grow older and change residences. The students living on campus usually have motion sensor lights so they do not have to remember to turn on and off their lights, they also do not have control over their thermostats. Comparing the graphs (figures 4.1 and 4.3) you can see that about 20% of students who live in private accomodations have motion sensored lights, whereas close to 90% of the students who live on campus have motion sensored lights. Even though the majority of the students living off campus do not have motion sensored lights, about 85% of the students still report that they always/most of the time turn off their lights. However, it appears that as students move off campus they become less responsible with adjusting the temperature of their thermostat. About 35% more students said that they have a programmable thermostat if they live off campus. The responses received from the students living off campus were significantly more varied, where the majority of the students living on campus either always/most of the time or rarely set their thermostat to 18°Cor lower if they had an adjustable thermostat.

The Student Union Lifestyle survey was administered in 2014 and consisted of 25 questions that asked about various habits and perceptions of students regarding the environment, energy, waste management, and climate change. The survey received a total of 933 responses. The questions we chose to analyze focused on helping the environment. Specifically, we looked at the following questions:

- To what extent do you agree, if at all, with the following statement? It's not worth me doing things to help the environment if others do not do the same.
- To what extent do you agree, if at all, with the following statements? It's only worth doing environmentally-friendly things if they save you money.
- To what extent do you agree, if at all, with the following statements? I find it hard to change my habits to be more environmentally friendly
- Which of these best describes how you feel about your current lifestyle and the environment?

When students were asked whether it is not worth being sustainable if others are not also acting sustainably, the majority (67%) responded with either strongly disagree or disagree. While only a small amount (15%) either agreed or strongly agreed. When asked if it's only worth being environmentally friendly if they can save money, two thirds of students either strongly disagreed or disagreed (65%) while only 15% felt as though they needed monetary incentive. This shows that most students feel as though their contribution to helping the environment is valuable despite what others do. Additionally, the students were asked whether they though changing their habits to be more environmentally friendly would be difficult. Nearly a quarter (23%) strongly agreed or agreed, while most students disagreed (43%). Most of the students (73%) also said that they would want to do more to help the environment.

These data suggest that students believe helping the environment is important, despite what other are doing or if there is a monetary incentive. Most students also believe that it would not be difficult for them to change to more environmentally friendly behaviors. Additionally, most students say that they want to do more for the environment. This suggests that students are willing to help the environment and address their habits. The data from this survey supports the claim that our campaign can potentially help students change their energy and heating behaviors.

The Energize Worcester Phase II survey was administered in the spring semester 2017 to students living in privately owned flats, and consisted of 55 questions. There were a total of 133 responses. The survey covered topics such as details of the student's home and how utilities are managed, the students knowledge and use of their heating system, as well as questions about sustainability knowledge and perceptions. The analysis of this survey by the Energize Worcester Spring 2017 team can be found in their initial report (White, et al., 2017). In our analysis, we focused on questions about sustainability, how the students feel about their own behaviors and how they manage their energy. We looked more closely at the following questions:

- If you have significant concerns about future sustainability, what is the most important element that you think you personally could influence?

- To what extent do you think technological developments may provide some solutions to environmental challenges?
- What is the most challenging aspect of managing your house's energy use?
- In colder months of the year, do you personally find the temperature in your room/common areas generally too warm, sufficiently warm, tolerably cold or too cold?
- Has your household made any conscious attempts to reduce its energy consumption in the house since you began the tenancy?

When the students were asked about what personal influence they believed they could have in future sustainability, the students provided a variety of answers. These responses are shown in Figure 4.5 below. The vertical axis of Figure 4.5 lists the responses given and the horizontal axis represents the number of students that provided the response.

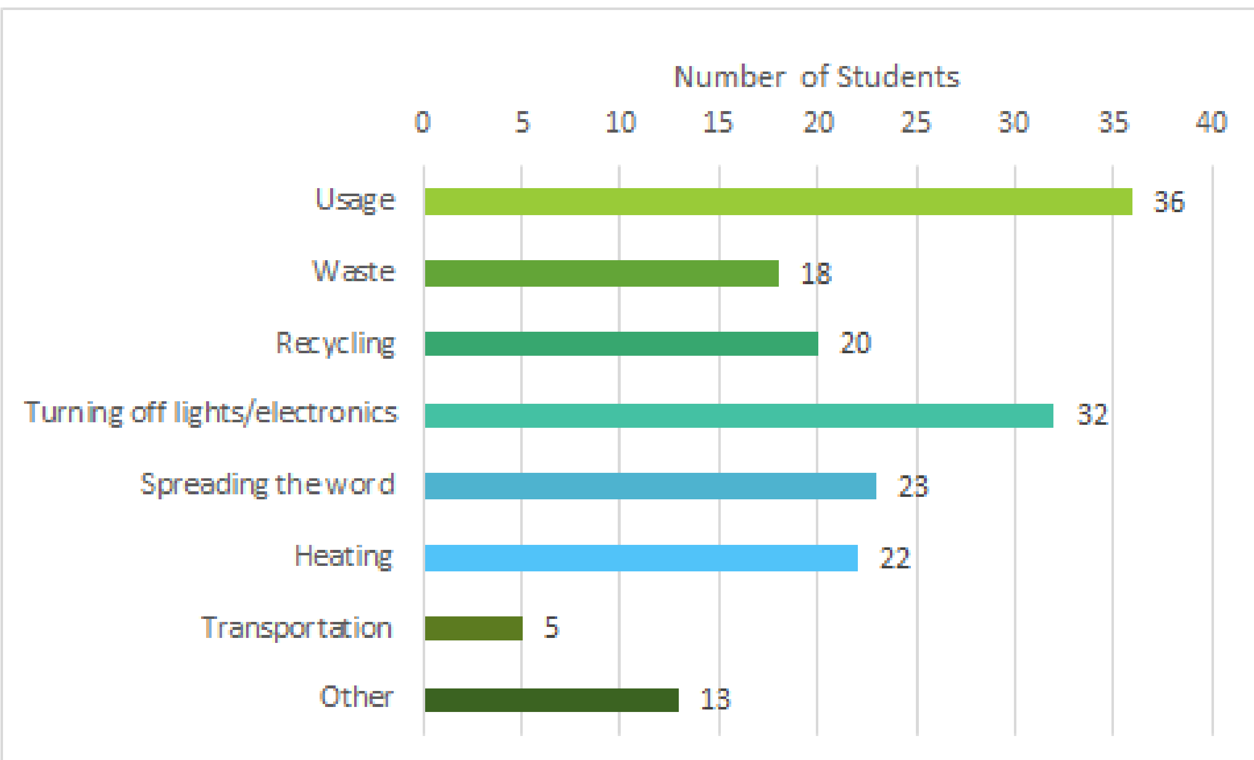


Figure 4.5

Responses to the question: "If you have significant concerns about future sustainability, what is the most important element that you think you personally could influence?"

The students proposed many way for them to influence future sustainability, with the most popular being behaviors related to personal usage of energy and heating, making conscious efforts to turn off lights or electronics when not in use, educating other about sustainability, recycling and waste management, and choosing more eco-friendly transportation. The most relevant categories to our project are the usage and heating categories. Both of which were fairly common answers, as seen in figure 4.5, with usage the most popular with 21% of student responses and heating given by 13% of the students. This suggests that students are aware that their energy and heating usage is something that they can change to be more sustainable. It is important to note that this question was the thirty-fifth question within the survey, therefore the responses of this question could have been influenced by previous questions.

Students were then asked whether they believed that technological developments could act as solutions to environmental problems. The responses to this question are shown in Figure 4.6 below. The vertical axis represents the number of students responses and the horizontal axis shows the score from 1 to 10 that the students gave. A score of 1 represents a strong belief that technology can not be useful to solving environmental problems, and 10 meaning that they strongly believe that technology can solve environmental problems. The scores are organized into five bins— 1 to 2, 3 to 4, 5 to 6, 7 to 8, and 9 to 10.

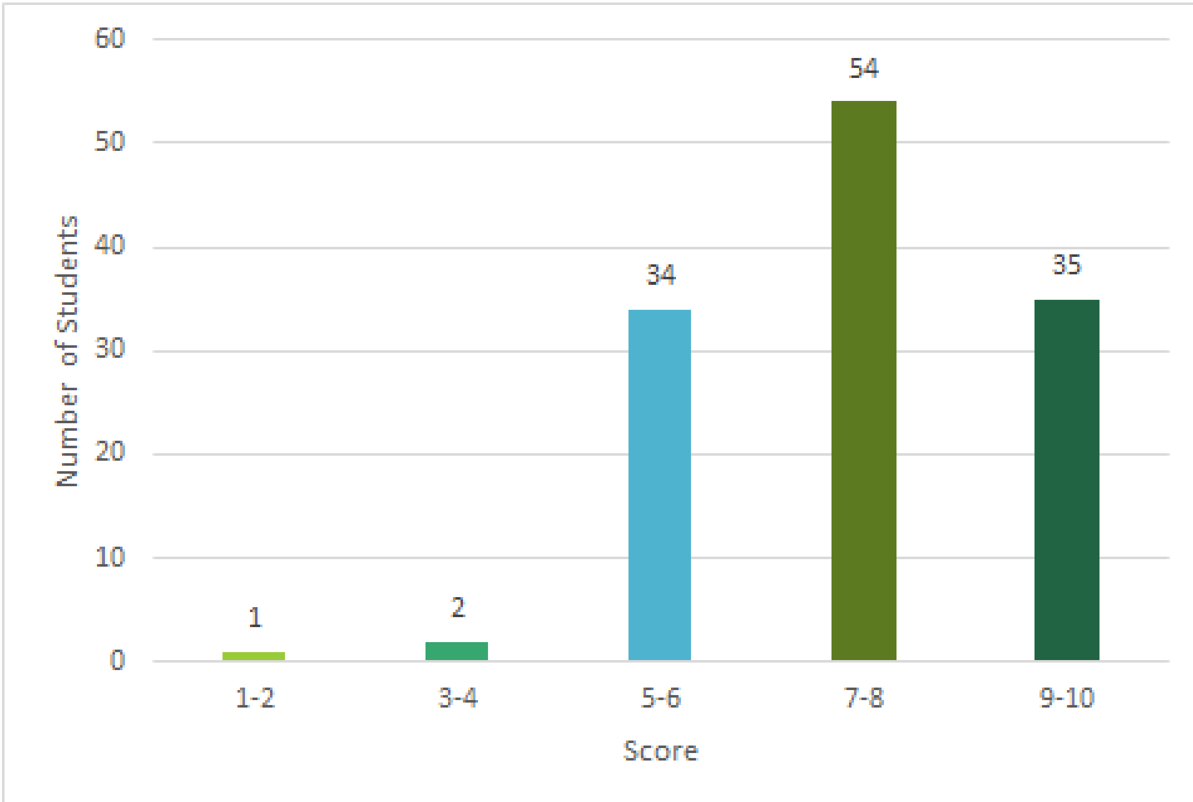


Figure 4.6
Responses to the question: "To what extent do you think technological developments may provide some solutions to environmental challenges?"

Almost all of the students surveyed gave either a neutral or positive score to the question. The majority of students (71%) gave a score between 7 and 10, suggesting that they believe technology will be important to solving environmental issues in the future. These data could also suggest that students may be open to using smart heating technology as a way to manage their heating, or view smart heating as a tool to manage their energy usage.

From the results of this survey, there is a significant portion of students who actively try to manage their energy and heating usage and view this usage as a behavior that can change in order to be more sustainable. The majority of students also believe that technology can help solve environmental issues. This suggests that students may be willing to use smart technology to help them manage their energy usage, especially with students that are already more mindful about it. This survey also reveals some of the challenges students are experiencing that may be prevent them from acting in more sustainable ways. Some of the most common challenges described were issues related to disagreements between flatmates, problem with their heating systems, and difficulties giving up their usage habits. While flatmates related issues and problems with heating systems are not challenges we can address, we can try to address unwillingness to change habits in our efforts to change student behavior.

The Energize Worcester team from Fall of 2017 conducted their version of the Energize Worcester Phase II survey on the students living in the five Wave-containing HMOs. The analysis of this survey by the Energize Worcester Fall 2017 team can be found in their initial report (McAteer, et al., 2017). Their survey consisted of 45 questions which mainly focused on the heating system used in their flat and how they managed their energy usage. There were a total of 14 responses across the five different residences. Despite there being such a small sample size, the information provided from these surveys are extremely useful. Since the student responses are directly tied to the residences they live in, we can compare their responses to the survey questions to the data gathered from the Waves installed in their homes. This allows us to gain context and begin to understand why the heating data acts in certain ways. For example, in HMO1, the students living there do not have direct control over their thermostat. It is the landlord that has complete control over their heating, and most likely sets a heating schedule for the flat. This would explain why the data from their residence is fairly consistent. More comparisons between student responses and heating data is discussed in section 4.3.

4.1.2 Findings from Free Listing and Focus Groups

The free listing activity consisted of three questions asked to students on the University of Worcester campus. Question 1 refers to the question: “Please list all of the things you would think of when you hear the word sustainability, for example, what activities or behaviors do you consider to be sustainable?”, question 2 refers to the question: “Please list why saving energy is important, and what are the reasons to save energy?”, and question 3 refers to the question: “What are all of the things that would prevent you from saving energy, for example what challenges would you experience that would discourage you?”. There were a total of 25 respondents from the University. Responses from the students were recorded and coded to condense answers into general themes and items for analysis. List analysis via generation of scree plots and proximity matrices were made for responses to each question.

The scree plot for question 1 is provided in Figure 4.7 below. The responses to the question are ordered on the horizontal axis by frequency within participant responses.

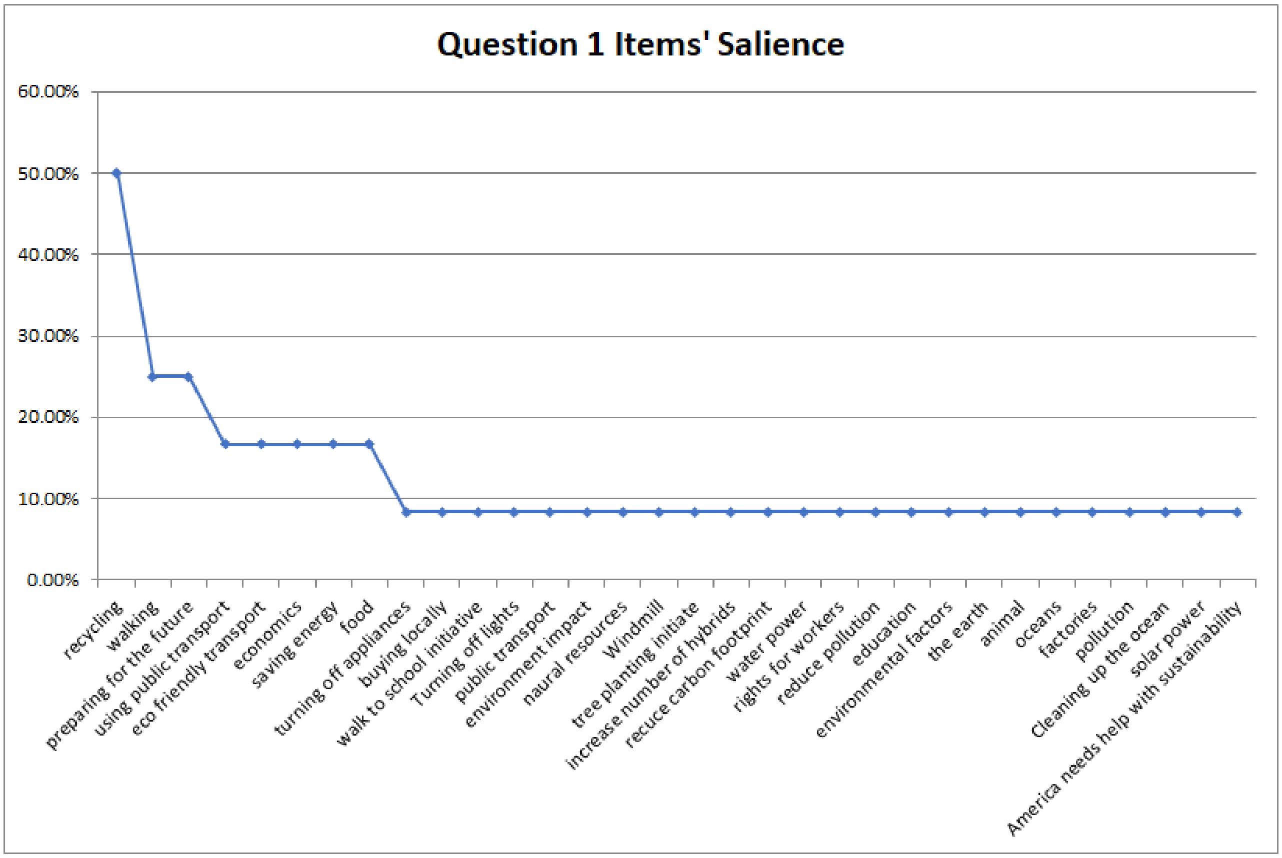


Figure 4.7

Responses to the question: "Please list all of the things you would think of when you hear the word sustainability, for example, what activities or behaviors do you consider to be sustainable?" The vertical axis represents percentage of item salience and the horizontal axis represents free list responses.

Shown in Figure 4.7, the most salient items given by students were "recycling", "walking", and "preparing for the future". Items that are also relevant are: "using public transport", "eco-friendly transport", "economics", "saving energy", and "food". This means that students mostly associate sustainability with recycling, preparing the world for future generations, and using more sustainable transport. It appears as if saving energy is considered related to sustainability, though it is not one of the major items. When comparing items pairwise for proximity, the items that appear closely are recycling and saving energy with a proximity score of 20, walking and using public transport with a score of 25, and using public transport and eco-friendly transport with a score of 33. The lower the score, the more closely clustered the items are. This means, when a student mentions recycling, it is very likely that the next item they list would be saving energy. There is also a connection between different types of transportation. It is logical to have public transport and walking and eco-friendly transport and public transport to be in such close proximity as they are very similar concepts. An interesting connection emerged between recycling and saving energy since the relation between the two is not as obvious as the types of transportation. The closeness of these two concepts may suggest that students believe that saving energy is of similar importance to recycling.

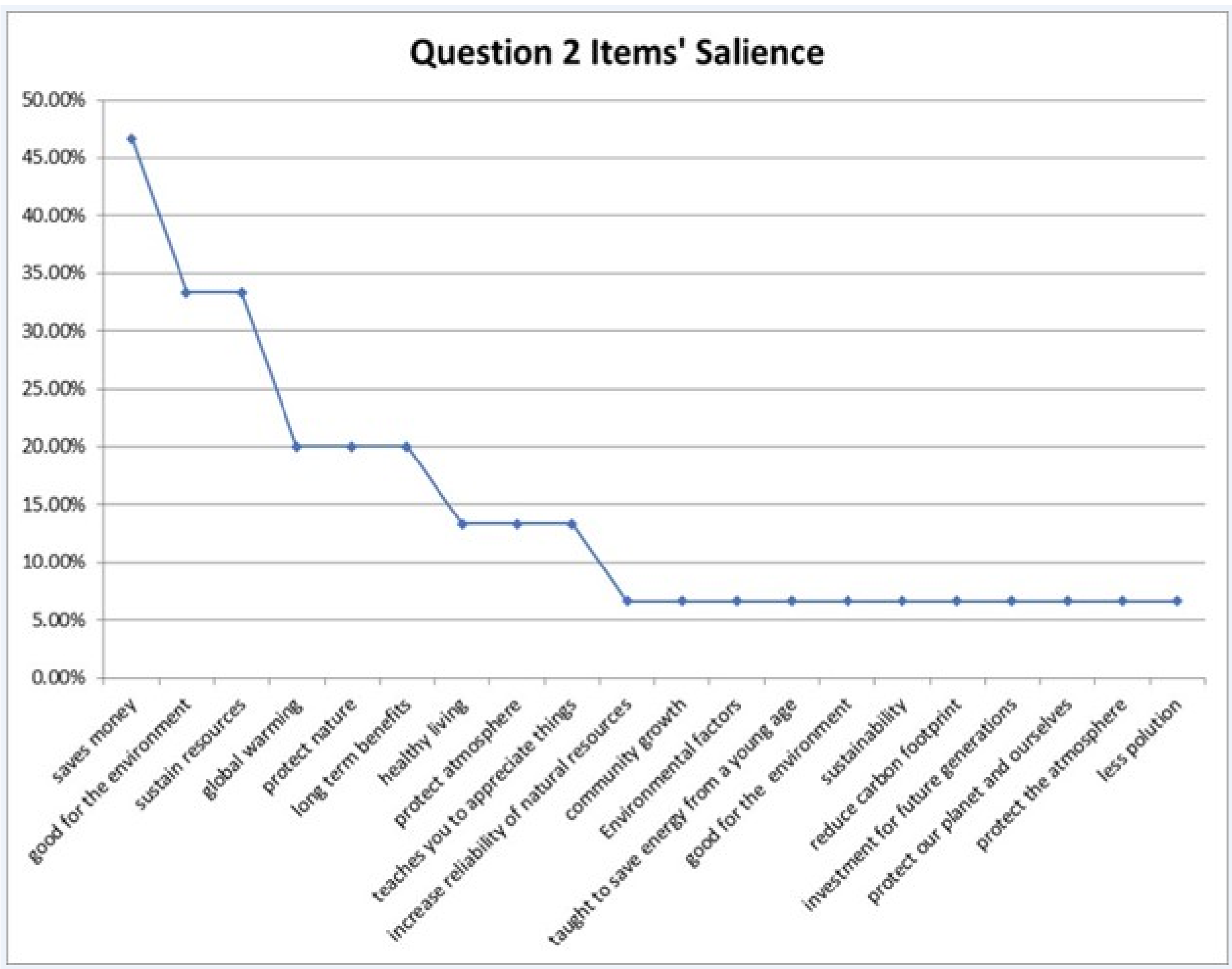


Figure 4.8

Responses to the question: "Please list why saving energy is important, and what are the reasons to save energy?" The vertical axis represents percentage of item salience and the horizontal axis represents free list responses.

Figure 4.8 represents student responses relating to why saving energy is important. The most relevant responses given include: “saves money”, “sustain resources”, “good for the environment”, “long term benefits”, and “global warming”. While the most popular response to why would you save energy is for monetary reasons, the other major answers related to helping the environment and ensuring that future generations have access to resources. In fact, saving money and sustaining resources have the same salience. This would imply that students could be motivated by reasons that are not directly tied to personal gain to act in sustainable ways. When looking at the proximity matrix, the most closely related phrases are “healthy living” and “protect nature”, “global warming” and “protect atmosphere”, “healthy living” and “protect atmosphere”, and “sustain resources” and “protect nature”. It appears as if the students surveyed connect their personal health with the health of the environment.

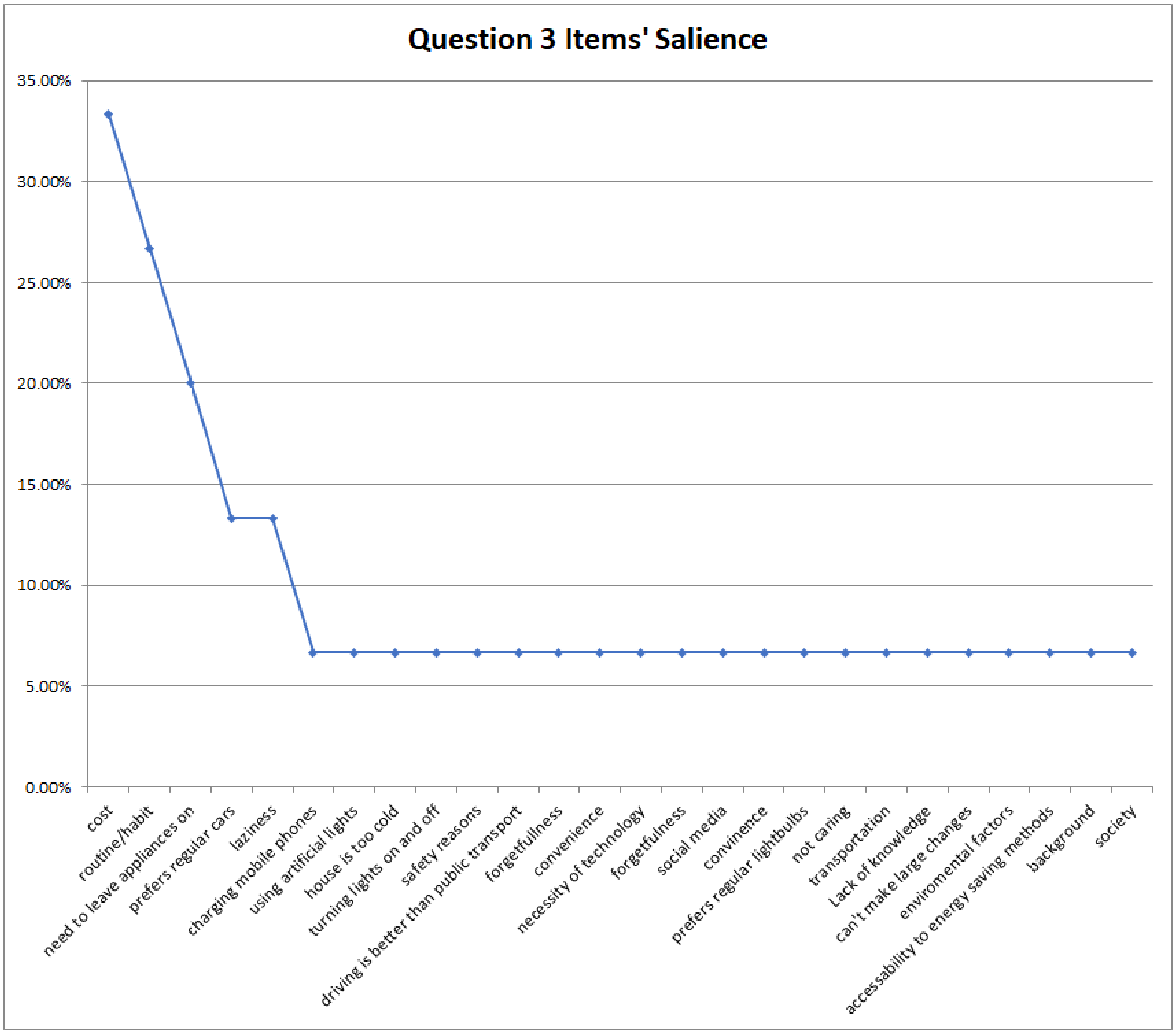


Figure 4.9

Responses to the question: "What are all of the things that would prevent you from saving energy, for example what challenges would you experience that would discourage you?" The vertical axis represents percentage of item salience and the horizontal axis represents free list responses.

Figure 4.9 represents responses the students gave when asked what challenges they experience when trying to be sustainable. The most salient responses include: "cost", "routine/habits", "need to leave appliances on", "prefers regular cars", and "laziness". It appears as if the major obstacles in getting student to be sustainable would be addressing the extra cost they feel goe into being sustainable, as well as getting students to feel comfortable changing or adopting new habits. When comparing items in with a proximity matrix, the only pair with a relevant proximity score was "cost" and "prefers regular cars" with a score of 33.

There does not appear to be any major connections between responses given regarding items that would prevent you from acting in a sustainable manner.

After the free lists were collected, our group held two focus groups to better understand how students at the University of Worcester think about sustainability. Both focus groups were asked the same set of seven questions. The questions that we asked the students were focused on their opinions of sustainability and energy conservation and their own contributions to being sustainable.

When asked about what sustainability means to them and what they think sustainable habits are, the main topics that the students discussed were: the 6 R's (recycle, rethink, redue, reuse, refuse, and repair), saving energy, planning for the future, turning off lights, water conservation and heating efficiency. When asked what they could do to be more energy conscious and what motivates them to be conscious about their energy use the students discussed topics such as: managing their water usage, turning off lights and appliances, using green energy, recycling, the environment, and future generations. During the discussions the students also put a significant emphasis on low quality of the housing at the University of Worcester and the city of Worcester in general. Many of the students talked about how the housing here works against you when you are trying to save energy and conserve heat. They also discussed the importance of education and staying informed when it comes to sustainability and energy conservation. The students also brought up that specifically on the University of Worcester's campus their needs to be an initiative put into place to educate the student on sustainability and energy conservation.

The responses from the free lists and focus groups have shown that out of the students who participated, many felt that energy conservation is an important aspect of sustainability. Many of the respondents had similar responses like this however, only a few correlated heating control with energy conservation and sustainability. The students tended to relate sustainability and energy conservation with larger scale ideas relating to power infrastructure such as the adoption of wind, solar and hydro power.

4.2 Energy Use in Wave Containing HMOs

The analysis software we developed allowed our team to analyze and understand the actual heating habits of students in order to compare them to their self-reported behaviors found in the surveys and focus groups. We used the program to analyze all five houses on a specific day, a single house on a specific day, as well as an average of a single house across the several months of data that we have access to.

4.2.1 Understanding the Collected Data

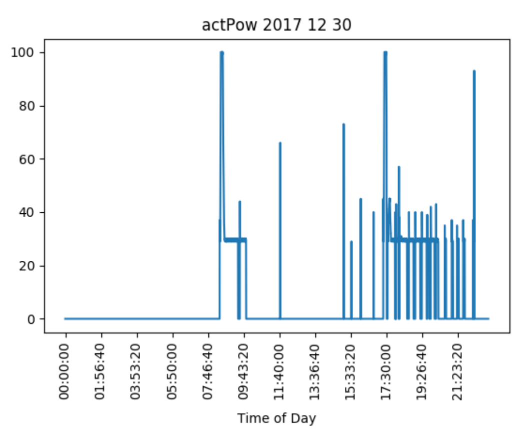
With the vast amount of data collected by Worcester Bosch Group, we needed a way to better understand the over 3.6 million data points that we were given. The data is split among the five houses, each day contained in a separate data sheet, leading to over 300 spreadsheets that needed to be analyzed. The first stage of our analysis involved cleaning the data, which was necessary due to the inconsistency of the 3rd party collection mechanisms. A small portion of our data has been filled in to the best of our ability. We made the assumption that if the data collector did not put a value in a given column that we would fill it with the most recent value the came before it. The data collector records data every ten seconds, giving an expected 8,640 data intervals for a given sheet on a given day. Due to the inconsistency of these 3rd data collectors, many sheets did not have the expected number of entries and as such made lining up the timestamps across days nearly impossible because of the recorders not actually recording data every ten seconds. To compensate for this, we disregarded any data sheets that had significantly less than 8300 entries. We then cut each longer data sheet to a length of 8300 entries for uniformity.

Of the seven variables that were accessible, our group focused primarily on the Actual Power, the Central Heating Active, Primary Temperature, and Primary Temperature Setpoint. Actual Power is the power being taken in by the system; it is a good representation of the demand that the system is under. Actual Power does not directly indicate any one function that the boiler is using, but rather that the boiler has a demand for some sort of heating or hot water. The Primary Temperature is the temperature coming out of the boiler. The temperature coming out of boiler does not necessarily reflect the temperature in the home that is being heated, rather it is a secondary indicator of how hot the boiler is running and by extension what is the demand on the boiler. Primary Temperature Setpoint acts similarly to Primary Temperature in that it represents the demand that the system could be under. Primary Temperature Setpoint is an arbitrary value that the boiler sets for itself when there is a demand for heating. The setpoint can be indicative of how much demand the heating system can be under. When the setpoint is low, the system is typically not under a high heating demand, and when it is high the system is in use. Central Heating Active is a logical variable that indicates whether the heating is on or not. A logical 0 means that the heating is off and any value that is not 0 represents the system being on.

Between these four variables, inferences can be made about the use of the system by the students in the homes. By using our custom software, our team was able to investigate all five HMOs across several days to identify their average usage habits.

4.2.2 Daily Data Analysis

One functionality of the custom software is the ability to investigate any variable in any home on any day. We chose to look more closely at HMOs 1 and 2 because they represented the best dichotomy of energy use throughout an average day. The inferences drawn about these homes can be made by looking at the four variables discussed above.



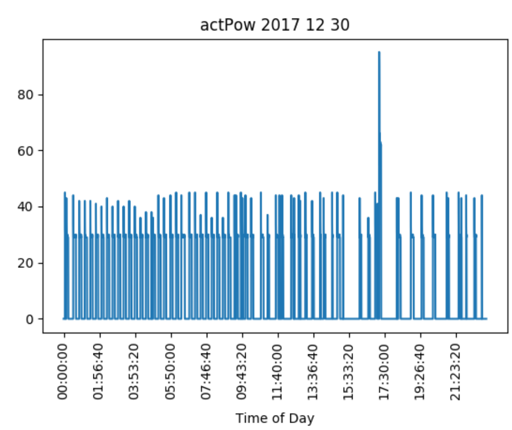
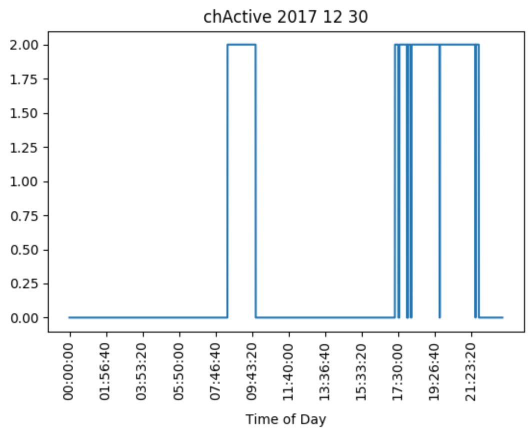


Figure 4.10a: Actual Power in HMO 1

Figure 4.10b: Actual Power in HMO 2



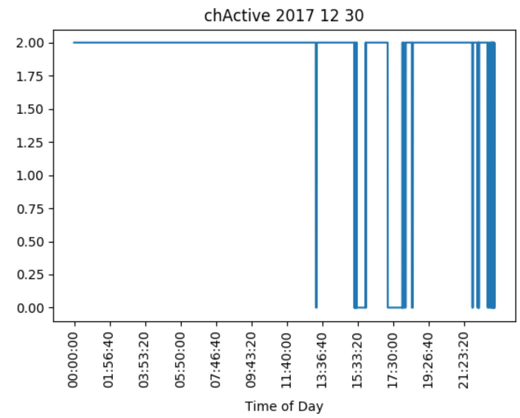
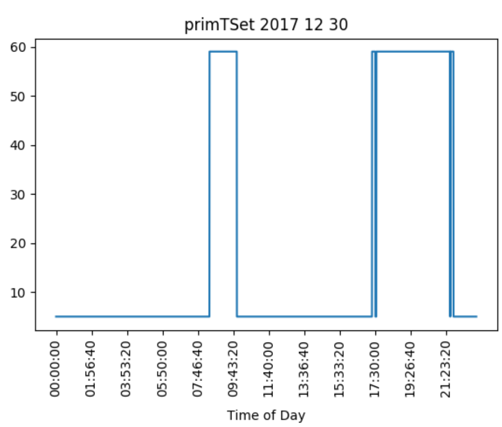


Figure 4.10c: Central Heating Active in HMO 1

Figure 4.10d: Central Heating Active in HMO 2

As shown in figures 4.10 a-d above, HMO 2 appears to be using more power during the day than HMO 1. The boiler in HMO 1 had far fewer demands for power throughout the day compared to HMO 2. The central heating demand mirrors the overall demand of power on the systems in both HMOs, with HMO 1 having significantly fewer instances of the heating being turned on. The central heating and actual power graphs can be easily compared with the Primary Temperature Setpoint graphs shown below. The changing of the setpoint in both graphs directly reflect the changes in power demand of both systems.



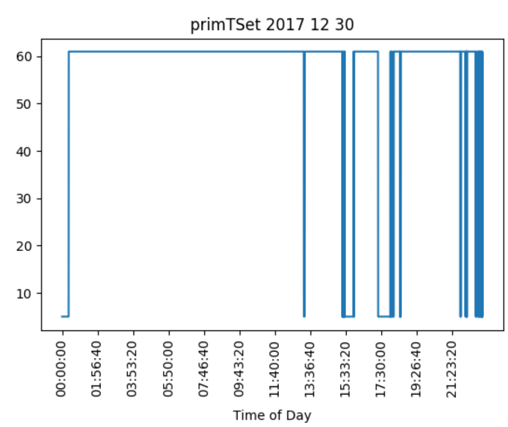


Figure 4.11a Primary Temperature Setpoint in HMO1

Figure 4.11b Primary Temperature Setpoint in HMO 2

All three variables Actual Power, Central Heating Active, and Primary Temperature Setpoint show two distinctly different levels of heating demand between these two HMOs. In HMO1, the Primary Temperature Setpoint, figures 4.11a and 4.11b, are set to active during morning and afternoon time zones and the Actual Power variable shows that the heating is on during those times. Contrastly, in HMO2, the Central Heating, Primary Temperature Setpoint, and Actual Power are consistently active throughout the day.

4.2.3 Averages Across Time Slots

Another functionality of the software is to analyze the data 'by time' which involves taking multiple days and averaging the values for each timestamp across those days. This analysis results in plots that can show what times are more likely to have a higher demand on the heating system. This in turn represents the probability that there will be demand on the system, allowing our team to better understand what is likely to be happening at any given time of day in any of the five HMOs. The graphs in this section are a representation of hypothetical demand on the boilers at a given time. The higher the value on the graph, the more likely it is that the system is under a demand at that time. In the Central Heating graph, figure 4.12a, we are able to see that there is a high chance that the heating is off in the early morning and is very likely to be on during the middle of the day.

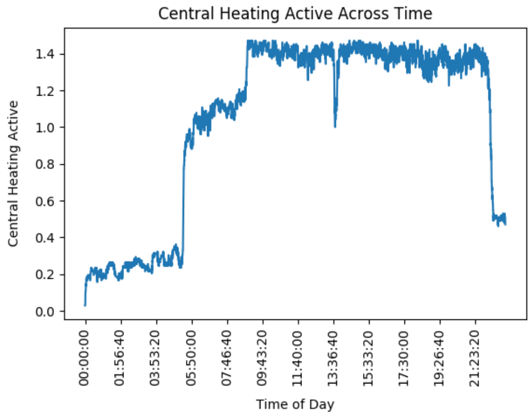


Figure 4.12a: Average Central Heating in HMO1

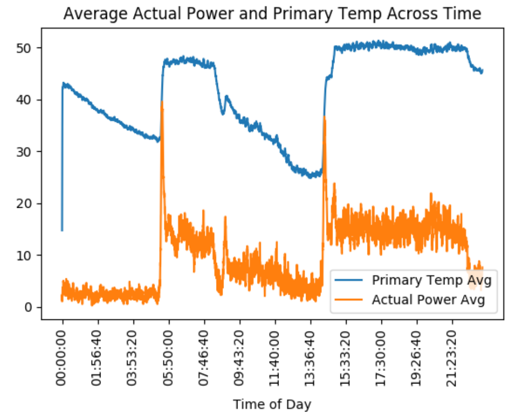


Figure 4.12b: Average Primary Temperature and Actual Power in HMO1

As seen in figure 4.12b, the values of the actual power system show two distinct zones in the graph that are more likely to have a high demand. It can be seen that the demand of Actual power just before 6:00 am shows that on any given day there is a high demand at that time for power in the system. The energy usage can be seen to follow a trend similar to that described in Section 4.2.2, most days will follow a pattern of two large spikes in energy demand. The HMO seems to be showing efficient trends throughout the days recorded.

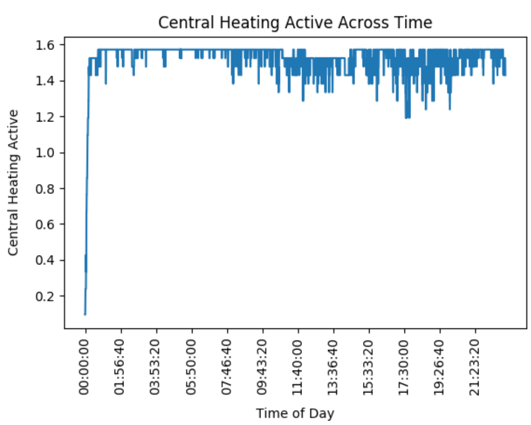


Figure 4.13a: Average Central Heating Active in HMO 2

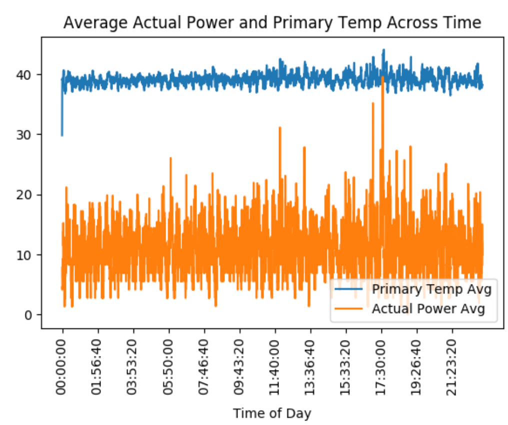


Figure 4.13b: Average Primary Temperature and Actual Power in HMO 2

Out of the five HMOs, HMO2 showed the most active heating, as represented by the results shown in figure 4.13a. Based on the Central Heating graph for HMO 2 (figure 4.13a) we can assume that the heating system will be on most of the time throughout the day, using energy the entire day. As seen in Appendix I, HMOs 3, 4, and 5 display similar energy activity throughout the day.

4.2.4 Averages Across Houses on a Certain Day

A third functionality of the data analysis software is to analyze all of the days that have data recorded for all five houses under observation. This process allowed our team to view trends in energy usage and heating behavior across the five houses in Worcester on a given day. Out of all the data collected, there were twenty one days that had data recorded across all five HMOs. This functionality works by taking a day and averaging the data from all five HMOs on that day 'by time', as described in section 4.2.3, resulting in the average demand for all of the homes on that day.

The first day chosen was January 26th, 2018. The graphs in the section show the values of the four main variables discussed above. Similar to the graphs in Section 4.2.3, the graphs in this section are representations of the average demand from all five houses on the given day. From the Central Heating graph below, figure 4.14a, at around 1:45 pm, because of the spike downwards, it shows that the heating is on in some of the houses while off in others. Additionally, at 4:00 pm when the graph spikes upward, it is incredibly likely that the heating is on in all five houses.

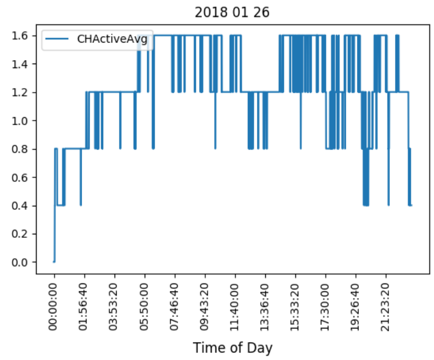


Figure 4.14a: Average Central Heating across five HMOs on 01/26/2018

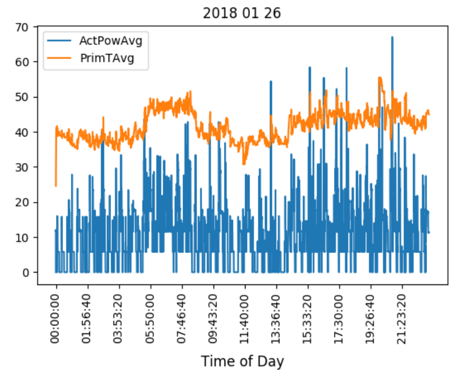


Figure 4.14b; Average Actual Power and Primary Temperature across five HMOs on 1/26/2018

As seen in figure 4.14a, the average of the houses central heating activity is high throughout the day. Four out of the five houses are on for most of the day, showing that the majority of the houses had a high energy demand. The average primary temperature is also very high for most of the day, implying that the boiler was constantly under some sort of heating demand. When putting the results from these different variables together, it can be seen that on January 26th the majority of the five HMOs had a high energy demand. The next day chosen was February 15th, 2018. It shows a significantly different set of demand on the heating systems across the five HMOs.

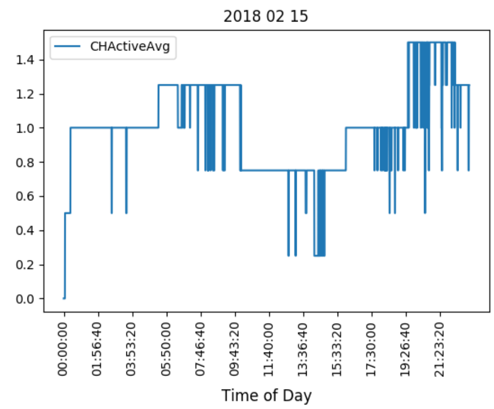


Figure 4.15a: Average Central Heating across five HMOs 02/15/2018

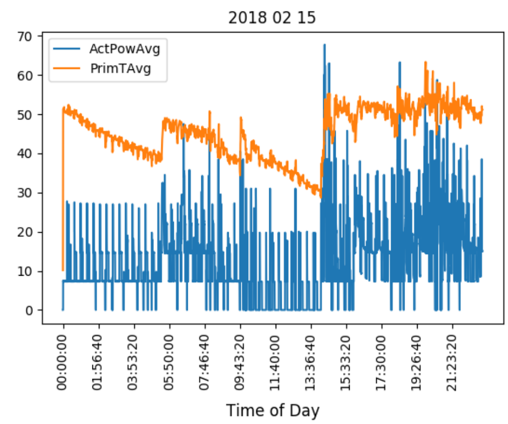


Figure 4.15b: Average Actual Power and primary temperature across five HMOs 02/15/2018

As shown above in figure 4.15a, there are two distinct time blocks where the heating was active during the day. Only some of the heating systems in the HMOs were on during the early parts of the day, while in the evening the majority of the heating systems were on. The primary temperature average followed this trend as well with a significant drop in heating demand from all systems in the early morning after night time and the early afternoon, shown in figure 4.15b. The average primary temperature appears to be high throughout most of the day with two major heating demand spikes in the middle and at the end of the day. The actual power demand of the systems reflects these spikes in the average temperature of the boiler.

4.3 Relationship Between Reported and Actual Behaviors

The technical data from Worcester Bosch in isolation provides a very narrow view of the demand on boilers in student homes. Survey data, while providing information about students opinions, are not always accurate due to response biases. While heating data or survey data alone cannot provide a true understanding of the behaviors of students living in HMOs, using both sources of information can provide us with a more complete picture of their lifestyles. Through studying the Worcester Bosch data and responses from the Fall

2017 Energize Worcester survey, we are able to identify what is happening to the boiler in relation to what students say about their lifestyles. Specifically, we can compare the two types of data from both HMO1 and HMO2.

In HMO1, the data from the Wave showed a varied demand on the boiler throughout the day. The most active parts of the day were briefly in the morning and then again in the late afternoon and evening. This activity appears to be intentional, as students living at the property claim to set a timer on their thermostat to control the temperature of their flat throughout the day. The students also say that they adjust the thermostat weekly and that when feeling cold in their home, they choose to put on more clothing. With this additional information, we are able to determine that students are aware of their heating use and actively try to manage their heating.

In HMO2, the demand on the boiler was much more consistent throughout the day. Looking at this data in isolation, it would appear as if the residents are using their heating inefficiently. With the addition of the survey data, however, this assumption would not be accurate. The students living at HMO2 personally do not have the ability to control their thermostat, as the landlord as full control over their heating. Even when the students feel too warm, they cannot adjust the temperature to cool down their rooms. Therefore, they are not able to take advantage of the Wave's functionalities that would manage their energy use efficiently.

With a more complete understanding of how heating is handled in the HMOs we studied, we have determined that heating and energy management in student homes is a complex issue. There are many variables that may impact how efficiently the heating is used, such as whether the landlords controlling heating in their homes, the thermal efficiency of the buildings, and conflicting schedules of the student residents. Many of these variables cannot be directly controlled by students and must be kept in mind when addressing heating and energy management in student homes.

5. Conclusions and Recommendations

This section contains a set of recommendations for future iterations of the energize worcester project and how the Worcester Bosch Group can improve efficiency in student rented HMOs. Additionally there are recommendations for designing a campaign for changing student behaviors in Worcester UK.

For the continuation of the Energize Worcester project, our recommendation to future teams is for the design and administration of a campaign. The campaign should target the students attending the University of Worcester including the students living in the five HMOs under study. This campaign should be focused on promoting good heating control and sustainable practices to serve as a new baseline for future studies. Future projects can then compare the quantitative and qualitative data gathered in this project with data collected after the campaign is implemented to investigate if there is an improvement in the students behaviors.

5.1 Recommendations for Designing a Campaign

Based on student responses and expressed interest during the focus groups, we believe that a key part of improving energy use habits among students at the University of Worcester lies in designing and implementing a campaign to change student behaviors and educate them. Below we have detailed steps and ideas for designing and implementing a campaign.

Once the team determines what challenges the students experience regarding energy efficiency and sustainability, it will be essential to find a way to address those barriers and change their behaviors. They should plan to address the identified barriers through an interactive campaign. Studies have shown when information campaigns about energy efficiency are implemented the participants reduce their energy consumption by about 7.4% (European Commission, 2013). The campaign should include informational pamphlets, promotional materials, multiple workshops and interactive activities in which the University of Worcester students can participate. The goal of this campaign will be to get the students thinking about their behaviors and habits relating to sustainability and energy efficiency and how they can be improved. To design the campaign, a team should follow the six steps outlined by the Southern Regional Education Board (n.d.):

- Preliminary Research and Goal Setting
- Engagement of Sponsors

- Audience Research
- Strategic and Tactical Planning
- Implementation
- Monitoring and Reporting

By using the data collected by our team, a future team can focused on the planning, implementation and monitoring steps of the campaign. In the strategic and tactical planning step, the team should be researching the most effective ways to communicate their message and promote behavioral change through pamphlets and promotional material. We believe that using pamphlets and promotional materials such as posters in the campaign will be most effective because this would be the most time-efficient and effective way to communicate mass amounts of information to students living in the HMOs, as well as the general population of students attending the University of Worcester. Pamphlets will also provide the opportunity to interact with the audience of the campaign. Having something physical that the students can hold will reduce the chance that they will forget about the information right away. It also gives students the opportunity to pass on the information to others (Conquest Graphics Blog, 2017). There should also be signs strategically placed around the campus and in the residence halls with information regarding good sustainability habits. For example putting a sign by the sinks with information on how much water students can save by turning off the water while brushing their teeth. Additionally, planning and creating workshops for the students to attend is another option. These workshops should be geared towards changing the students energy conservation and efficiency behaviors. Studies have shown that educational campaigns that involve audience participation were more “effective in improving environmental behavior than those that did not” (Lynnette, 1999, p. 10). For a campaign the team should focus on holding multiple workshops and information sessions that will include interactive activities that will encourage participation from the University of Worcester Students.

In the implementation phase of the campaign, the primary focus should be distributing pamphlets to the students living in the HMOs and the general student body. The team should also distribute other promotional material around campus, such as hanging up posters and infographics. For the final step of monitoring and reporting, the data from the Wave heating systems will continue to be collected post campaign. This data will allow the University of Worcester and the Worcester Bosch Group to monitor the impact that the campaign has on the students.

5.2 Recommendations for Worcester Bosch Group

Through our detailed investigation of Worcester Bosch data, our team has drawn a set of conclusions and recommendations for the Worcester Bosch group regarding the use of the Wave systems in student homes or homes with similar living conditions. The primary issue regarding efficient heating in homes such as student rented HMOs lies in the fact that there are effectively multiple families living in a single family home. When looking at students in these five HMOs if we treat each occupant as a single family it becomes much clearer as to why the energy usage across the five houses cannot be distilled down to a single use pattern.

The most ideal way to configure heating in a house with an occupancy like student rented HMOs would be to set up a multi-zone heating system. A system like the Worcester Bosch EasyControl system would be much more effective in these student rented homes because it would allow students to heat their specific rooms without heating the entire home. This would allow for more efficient use of the boilers leading to overall energy savings. A multi-zone setup would also allow for students to configure their heating to turn on or off whenever they enter or leave their houses.

Overall we found that students want to be more energy efficient but without a heating system that suits their lifestyles it becomes much harder to utilize their system efficiently. By installing and configuring a system that matches the student's lifestyles it facilitates more efficient use of heating systems.

Appendices:

Appendix A: Informed Consent for Surveys

Informed Consent Agreement for Participation in a Research Study

Investigators: Ryan Kent, Samantha Randall, Ethan Schutzman, Alex Ward

Contact Information: wuk18energize@wpi.edu

Title of Research Study: Energize Worcester Project D'18

Sponsor: University of Worcester and Worcester Bosch

You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

This study will be used to evaluate habits and perceptions of University Worcester students living in HMOs and how they use the smart heating system, the Wave, installed in their home. This study involves students of the University of Worcester who have the Wave smart heating system installed in their homes. The surveys from this study will be used in conjunction with technical data from the Wave loggers in the houses of multiple occupation (HMOs).

You will be answering a series of questions regarding your personal habits when it comes to sustainability and energy conservation. The activity should last no longer thirty minutes.

We do not foresee any risks to answering the questions or participating in the activity. If at any point a question(s) or activity makes you feel uncomfortable you may choose to deny to answer the question and/or end the activity.

By participating in our research you will be providing us with information that we will use to improve your living comfort and improve the energy efficiency of your HMO. All information collected from you will be kept strictly confidential and anonymous. The data collected will be stored on a secured UW server with hard copies in a locked office. The only people who will have access to this data will be our research group and associated sponsors at the University of Worcester and Worcester Bosch Group.

If you want more information you can contact us at wuk18energize@wpi.edu or Professor Kent Rissmiller, Tel. 508-831-5019, Email: kjr@wpi.edu and Jon Bartelson, Tel. 508-831-5725, Email: jonb@wpi.edu.

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

__________________________ Date: __________________

Study Participant Signature

____

Study Participant Name (Please print)

___________________________________ Date: __________________

Signature of Person who explained this study

Appendix B: Informed Consent for Free Listing

Informed Consent Agreement for Participation in a Research Study

Investigators: Ryan Kent, Samantha Randall, Ethan Schutzman, Alex Ward

Contact Information: wuk18energize@wpi.edu

Title of Research Study: Energize Worcester Project D'18

Sponsor: University of Worcester and Worcester Bosch

You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

This study will be used to evaluate how students of University Worcester view and think about sustainability and saving energy. This study involves students of the University of Worcester. This data will be used to determine further research areas.

You will be responding to prompts about sustainability and energy conservation. You will be asked to list as many things as you can think of for each prompt. The activity should last no longer ten minutes.

We do not foresee any risks to answering the questions or participating in the activity. If at any point the activity makes you feel uncomfortable you may choose to deny to answer the question and/or end the activity.

By participating in our research you will be providing us with information that we will use to improve energy conservation and sustainability within the University of Worcester community.

All information collected from you will be kept strictly confidential and anonymous. The data collected will be stored on a secured UW server with hard copies in a locked office. The only people who will have access to this data will be our research group and associated sponsors at the University of Worcester and Worcester Bosch Group.

If you want more information you can contact us at wuk18energize@wpi.edu or Professor Kent Rissmiller, Tel. 508-831-5019, Email: kjr@wpi.edu and Jon Bartelson, Tel. 508-831-5725, Email: jonb@wpi.edu.

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

_________________________ Date: _________________

Study Participant Signature

____

Study Participant Name (Please print)

__________________________________ Date: _________________

Signature of Person who explained this study

Appendix C: Informed Consent for Focus Groups

Informed Consent Agreement for Participation in a Research Study

Investigators: Ryan Kent, Samantha Randall, Ethan Schutzman, Alex Ward

Contact Information: wuk18energize@wpi.edu

Title of Research Study: Energize Worcester Project D'18

Sponsor: University of Worcester and Worcester Bosch

You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

This study will be used to evaluate how students of University Worcester view and think about sustainable and energy conservation behaviors. This study involves students of the University of Worcester. This data will be used to determine themes and strategies that will be included in the Energize Worcester campaign.

You will be responding to questions about sustainability and energy conservation. There will be a discussion between participants that will be moderated by one of our research team. This focus group is expected to last thirty minutes.

We do not foresee any risks to answering the questions or participating in the activity. If at any point a question(s) or activity makes you feel uncomfortable you may choose to deny to answer the question and/or end the activity.

By participating in our research you will be providing us with information that we will use to improve energy conservation and sustainability within the University of Worcester community.

All information collected from you will be kept strictly confidential and anonymous. The data collected will be stored on a secured UW server with hard copies in a locked office. The only people who will have access to this data will be our research group and associated sponsors at the University of Worcester and Worcester Bosch Group.

If you want more information you can contact us at wuk18energize@wpi.edu or Professor Kent Rissmiller, Tel. 508-831-5019, Email: kjr@wpi.edu and Jon Bartelson, Tel. 508-831-5725, Email: jonb@wpi.edu.

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

__________________________ Date: __________________

Study Participant Signature

____

Study Participant Name (Please print)

___________________________________ Date: __________________

Signature of Person who explained this study

Appendix D: Free Listing Prompts

Free listing Prompts

1. Please list all of the things you would think of when you hear the word sustainability, for example, what activities or behaviors do you consider to be sustainable?
2. Please list why saving energy is important, and what are the reasons to save energy?
3. What are all of the things that would prevent you from saving energy, for example what challenges would you experience that would discourage you?

Appendix E: Focus Group Questions

Focus Group Questions:

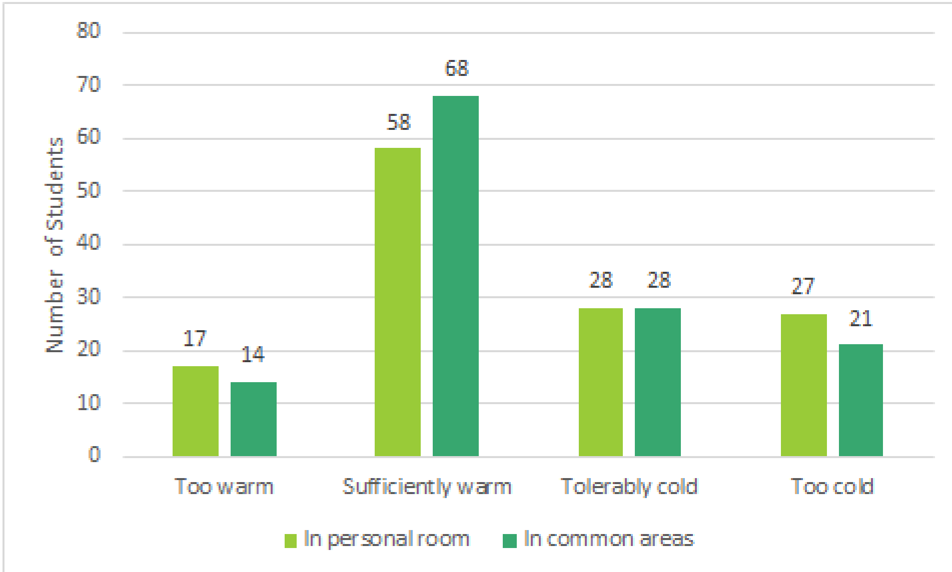
1. What does sustainability mean to you?
2. What are sustainable behaviors?
3. Who is responsible for sustainability?
4. How does energy conservation fit into you ideas of sustainability?
5. How can you be more energy conscious?
6. What would motivate you to be more energy conscious? Other than money?
7. What challenges are associated with participating in sustainable behaviors?

Appendix F: Energize Worcester Survey

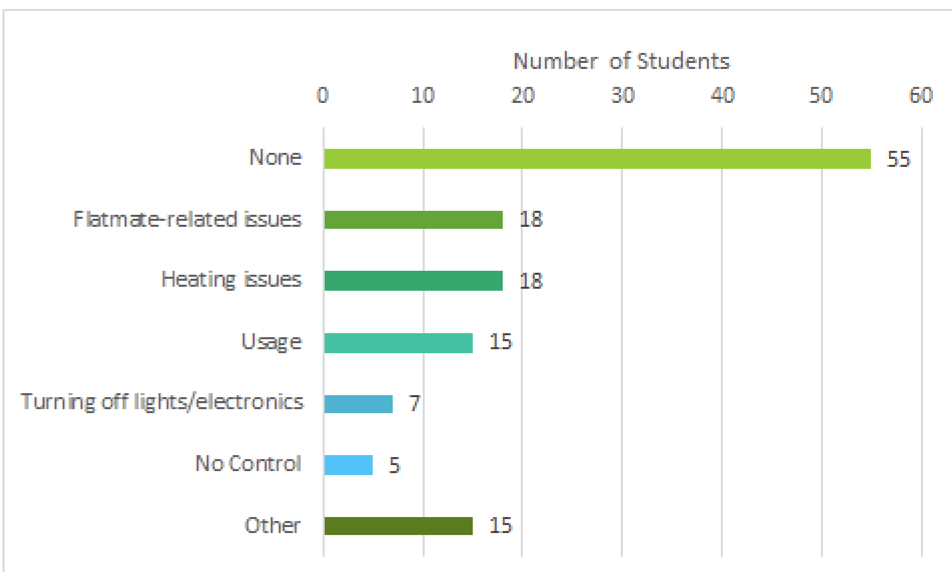
Appendix G: Student Travel Survey

Appendix H: Student Union Lifestyle Survey

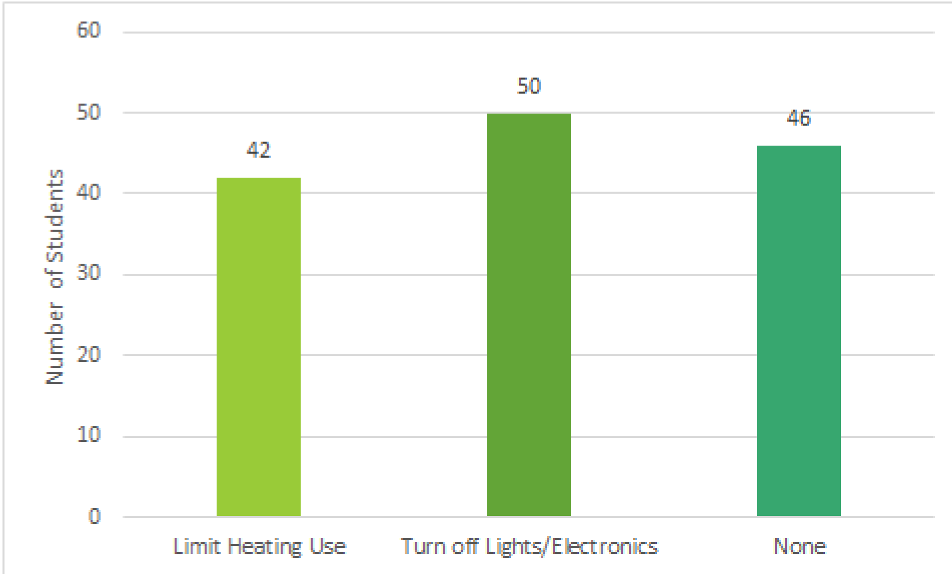
Appendix I: Additional Graphs from the Energize Worcester Survey



Responses to the question: In colder months of the year, do you personally find the temperature in your room generally too warm, sufficiently warm, tolerably cold or too cold?



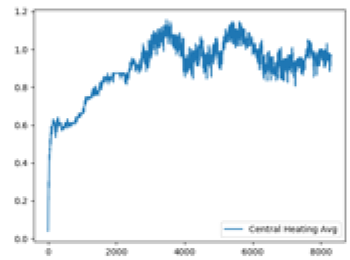
Responses to the question: What is the most challenging aspect of managing your house's energy use?



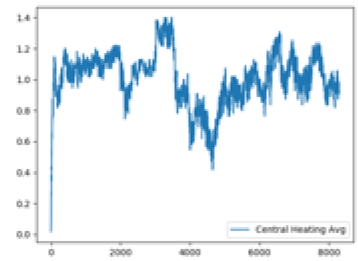
Responses to the question: Has your household made any conscious attempts to reduce its energy consumption in the house since you began the tenancy?

Students were asked questions about their households specifically. One question asked how they felt about the temperature in their personal rooms as well as the common areas of their homes. While many believed both their room and common rooms were sufficiently warm, 45% and 52% respectively, a significant portion of students felt as though their rooms were either tolerably cold or too cold, 42% and 37%. The students were then asked if they make any conscious choice to reduce their energy consumption. About a third of students responded that they do not consciously try to reduce their energy consumption. Of the 66% that do, 33% choose to limit their heating usage and 33% try to actively turn off their lights and electronics when not in use. Finally, when asked about what challenges they face when managing their home's energy usage, many students (41%) responded that they did not experience any challenges. Of the challenges mentioned, the most common were flatmate-related issues with 14%, heating issues with 14%, and usage with 11%.

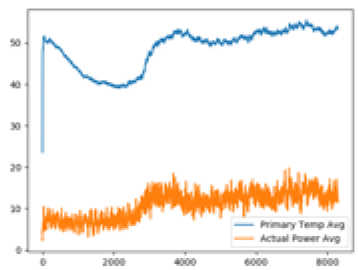
Appendix J: Additional Wave Graphs



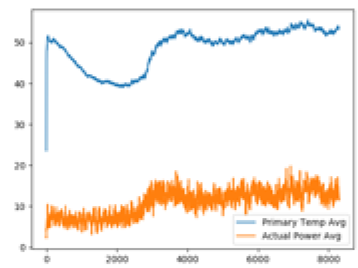
Average Central Heating Active HMO3



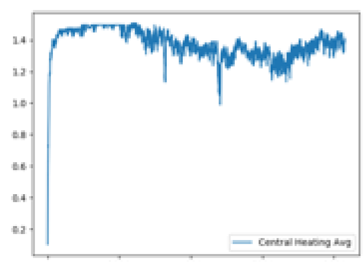
Average Central Heating Active HMO4



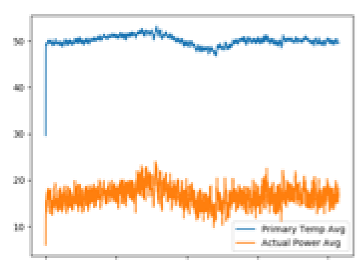
Average Primary Temperature and Average Actual Power HMO3



Average Primary Temperature and Average Actual Power HMO4



Average Central Heating Active HMO5



Average Primary Temperature and Average Actual Power HMO5

The above plots are the average by time slot plots for HMOs 3, 4 and 5. The Central

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