Energy Consumption of WPI Buildings

An Interactive Qualifying Project

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Abstract

This report examines the energy efficiency of Founders Hall and East Hall on the WPI campus. East Hall, a LEED certified building, is compared and contrasted to Founders Hall, a non-LEED certified building, by analyzing and evaluating electricity and gas consumption through a walk-through audit, meter recording, and surveys conducted in the winter season. Adding weather seals around doors, better placement of lighting, and prioritizing thermal comfort are some recommendations to improve energy efficiency.

Authorship

All group members contributed equally to this project. Jeremy focused on the energy audit, including background research, taking meter readings for East Hall, and performing walk-through audits of East and Founders Hall. He also worked on formatting, style, and editing the paper along with contacting Residential Services and Chartwells. Cheng worked on the background research of previous IQPs, the WPI Sustainability Plan, human behavior and energy consumption, the East Hall LEED scorecard, retrocommissioning, and SynergE. Cheng also focused on survey design, the analysis of the East Hall survey responses, and some analysis of energy consumption and energy bills. Bryan performed background research of Energy Star, BIM, and survey design. Bryan also worked on survey development using Qualtrics, survey distribution, analysis of Founders Hall and Res Services responses, writing about the findings and recommendations, and contributed to the proofreading of the final report. Douglas focused on researching LEED, performing energy audits, collecting and organizing the energy audit data including meter readings and temperature readings, and analysis of energy consumption.

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Chapter 1: Introduction

The idea of sustainability has raised attention all over the world for the past few decades. Sustainability is the goal of meeting the needs of the present without compromising the ability of future generations to meet their own needs [1]. Energy consumption is one of the largest fields that society can attempt to reduce to make the world more sustainable. An updated analysis published by the Lawrence Livermore National Laboratory suggests that the USA is just 39% energy efficient [2], meaning that more than half (61%) of the energy is ultimately wasted. This indicates a great potential for energy conservation and increased sustainability.

Worcester Polytechnic Institute (WPI) currently owns 39 buildings on its main campus [3] and thus consumes a fairly big amount of energy. As a community dedicated to promote the culture of sustainability, WPI is taking various steps to accomplish this goal. Some steps include the Sustainability Plan and SynergE, which will both be discussed in more detail later. Four of the five newest buildings on campus—the Bartlett Center, East Hall, the Recreation Center and Faraday Hall, underwent a certification process known as LEED certification to ensure that they were built in a sustainable, green manner. It is expected that these buildings operate efficiently, but LEED certification cannot guarantee efficient operation, as the certification is awarded shortly after construction. However, while the buildings may be designed to operate efficiently, occupants may not use the buildings in the way they were designed.

1.1: Goals

Our project had three primary goals:

1. To investigate the energy consumption and efficiency of selected buildings,
2. To determine behavioral issues of WPI constituency regarding awareness and attitudes toward energy consumption, and
3. To make recommendations on how to improve the efficiency and energy usage of the buildings analyzed

Goal 1: Evaluating Physical Issues

As part of our first goal, we evaluated the energy consumption and efficiency of each of our selected buildings. To satisfy this goal, we looked for things in the structure and equipment of the buildings that could be improved.

Goal 2: Evaluating Social Issues

We answered the question “How is building energy consumption affected by the behavior of the occupants?” To this end, we started with the assumption that the building designers, especially those of the newer, LEED certified buildings, expected a certain attitude towards building energy consumption and use. We attempted to identify this expectation, as well as any discrepancies between this expectation and the current reality of building usage. We then evaluated how these discrepancies affected the energy consumption of the building.

Goal 3: Making Recommendations

The recommendations we made encompassed the data we collected about both the physical inefficiencies of the buildings and the inefficiencies in the use of the building by the occupants. The recommendations identified areas for improvement and recommended concrete steps for implementation. An important aspect of this goal was to test our recommendations, especially those concerning changes in the behavior of building occupants.

Chapter 2: Background

In this section, information pertinent to a preliminary investigation regarding the current status of WPI's energy consumption is presented. Such information is useful in identifying existing problems and determining the methodology for the project. Topics that are covered in the background section include a review of previous student projects or Interactive Qualifying Projects on WPI buildings, review of WPI's plan on sustainability and the LEED certification process, collection and analysis of current utilities bills on WPI campus, examining retrocommissioning practices such as SynergE and Energy Star including their recommendations on energy conservation, and finally an overview of Building Information Modeling and how it is used in conducting an energy analysis.

2.1: Previous IQPs on Buildings

So far, there have been several Interactive Qualifying Projects (IQP) conducted by students at WPI about the energy consumption of different buildings on the WPI campus, including Atwater Kent Laboratories and Higgins Laboratories.

In 2007, "Monitoring Electricity Consumption on WPI Campus" examined the status of WPI's electricity monitoring system on a building-by-building basis [4]. It included a comprehensive report of electricity meter functionality for several dormitories and academic buildings and presented a short and long-term plan to improve the school's ability to monitor its electricity consumption. This project was mostly a qualitative analysis of energy usage and energy efficiency, because at that time, there was no single point source or sub metering for information on WPI's electricity metering system. Their findings were not quite satisfactory, showing that Higgins Labs consumes 25.8% of the campus electricity while Fuller Lab only uses 0.8%, and leaving 56% of the electrical energy used on campus unaccounted for. Reliability of this project is questionable due to this unusual result, and the findings of this project need to be verified. The figure below presents the energy consumption of each building according to their research.

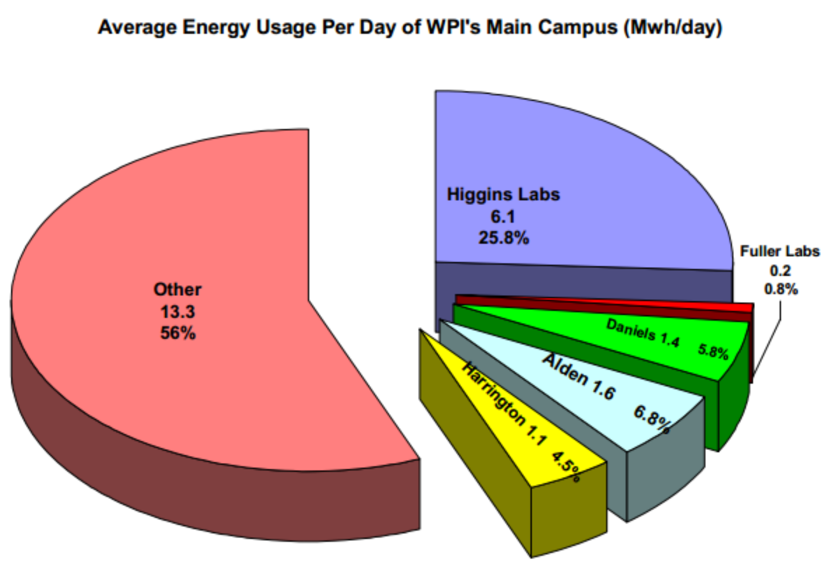

Figure 1: Percentage of average energy usage per day of the WPI main campus in 2007

In 2009, an IQP group conducted an energy audit of Higgins Laboratories to address its electricity consumption and to determine how to reduce the energy consumption of the building [5]. They recommended the following methods to reduce electricity usage:

1. Replace incandescent light bulbs with LED or fluorescent bulbs,
2. Reduce the light levels in most rooms, and
3. Install occupancy sensors in all rooms.

Furthermore, they suggested developing an ongoing relationship with National Grid to conduct up-to-date renovations and audits.

In 2010, a similar project focused on the reduction of power consumption in Atwater Kent. The "Atwater Kent Energy Audit and Solar Energy" project explored the energy consumed by Atwater Kent by looking at ways to reduce the determined electric power consumption, and the feasibility of placing solar panels on the roof of the building [6]. Their recommendations were:

1. Remove unnecessary light bulbs from fixtures reducing light levels of over lit rooms by approximately 30%,
2. Change the light bulbs that are in the fixtures to LED bulbs, which use 54% less power,
3. Edit the computer settings so that the computers shut down when not in use, and
4. Install a photovoltaic system on the roof of the building to produce electricity.

2.2: WPI's Sustainability Plan

> "We at WPI will demonstrate our commitment to the preservation of the planet and all its life through the incorporation of the principles of sustainability throughout the institution. We will accomplish this goal by promoting a culture of sustainability that incorporates the beliefs and behaviors supported by our technical strengths and by our heritage of the application of both theory and practice, as embodied in our motto, *Lehr und Kunst*, to the solution of important problems. WPI will develop a bold and comprehensive strategy to advance the three broad goals of sustainability: ecological stewardship, social justice, and economic security." —The WPI Task Force on Sustainability

In 2007, WPI established its Task Force on Sustainability to coordinate WPI's efforts to provide long-term sustainability campus-wide. The Task Force represents WPI's commitment to promoting a culture of sustainability to improve the quality of life for current and future generation, by taking advantage of its technical strength. In October 2013, the WPI's fourth annual Campus Sustainability Report was sent out by the Task Force, indicating the current status of progress in making the campus more sustainable.

The WPI community started a two-phased planning process in order to accomplish its goal to develop an innovative path to achieve sustainability. The plan [7] includes four major goals:

- **Goal 1: Academics**
  WPI will offer students opportunity to incorporate and evaluate the importance of sustainability through various sources of undergraduate and graduate curriculums and projects.

- **Goal 2: Campus Operation**
  The operation of WPI's campus and facilities should demonstrate the principles of sustainability. In order to achieve this, a number of specific objectives and tasks are developed, including reducing WPI utility consumption by 25% over 5 years.
- **Goal 3: Research and Scholarship**
  WPI will make significant contribution to the technologies, the policies and the attitudes that makes world more sustainable through research and scholarly activities.
- **Goal 4: Community Engagement**
  WPI's student, faculty and stuff should develop an attitude of promoting a culture of sustainability on campus, in Worcester, for the nation and globally.

Starting early in 2012, the first phase evaluated the current status related to sustainability of the four major aspects of WPI facilities and programs and identified broad goals for each of these components.

The Phase One working groups were charged with:

- Determining WPI's current status with regard to Sustainability in the working group's area,
- Benchmarking against other institutions as appropriate,
- Generating new ideas for advancing sustainability at WPI,
- Recommending specific goals for achieving key aspects of sustainability at WPI, and
- Identifying strengths/weakness/opportunities for enhancement of WPI's activities with respect to sustainability [7].

By 2013, the first phase was completed. As pointed out by the 2012 annual campus sustainability report, WPI met several sustainability goals, including preparation of sustainability courses, retrofitting of electrical sub-metering in several buildings, construction of better reporting structures to improve public awareness, and establishment a waste audit. Furthermore, three major tasks have been accomplished:

- Internal benchmarking of our sustainability activities at WPI,
- External benchmarking with regard to peer and aspirational institutions, and
- Development of potential goals and strategies.

The Sustainability Plan was completed by the summer of 2013, and goals mentioned above were met. Some of the major tasks and achievements include [8]:

- WPI currently offers more than 90 courses that address one or more aspects of sustainability
- Utility consumption is reduced by 25% over 5 years
- New buildings and all major buildings on WPI campus are LEED-certifiable
- At least 50% of the campus community is engaged in sustainability efforts
- Several projects are performed to investigate WPI's ground, energy consumption, greenhouse gas, transportation, water, waste and dining

2.3: Human Behavior and Energy Consumption

Although people are often aware of the benefits of using energy more efficiently, a variety of social, cultural, and economic factors often prevent them from following these practices [9]. Even when high efficiency technologies have been installed, 30 percent or more of the energy savings that could potentially be realized through such technologies are lost, according to the American Council for an Energy-Efficient Economy (ACEEE). In November 2009, Rep. Brian Baird (D-WA) said at a presentation at Environmental and Energy Study Institute that “we have tremendous opportunities for tremendous savings” and that the industrialized world should strive for 20 percent reduction in energy consumption in 20 weeks. The link between behavioral science and energy use will play a key role in solving our energy crisis, our economic crisis, and our geopolitical crisis.

Simple behavioral changes in the United States could result in a 25-30 percent energy savings, the equivalent of the energy produced by 240 medium-sized coal-fired power plants. This would prevent the emission of 500 million metric tons of carbon dioxide annually.

2.4: LEED Overview

Leadership in Energy and Environmental Design (LEED) is a globally recognized green building certification system with the goal of improving: energy savings, water efficiency, CO2 emissions reduction, and improved indoor environmental quality. Established in 1998 by the United States Green Buildings Council (USGBC), LEED certification provides third-party verification that a building, home, or community was designed to maximize positive environmental and human health and well-being [10].

The LEED rating system was designed for rating new and existing commercial, institutional, and residential buildings as well as neighborhood developments. The current LEED rating system offers four certification levels:

- Certified (40-49 points)
- Silver (50-59 points)
- Gold (60-79 points)
- Platinum (80+ points)

These levels of certification correspond to the number of points accumulated in seven green design categories: sustainable sites, water efficiency, energy and atmosphere, indoor environmental quality, innovation in design, and regional priority. Each category consists of prerequisites and credits, which are required elements or green building strategies that must be met before a project can be considered for LEED certification. These prerequisites and credits are provided as tools and strategies to achieve a level of LEED certification. Table 1, provides an outline of LEED rating systems for projects such as New Construction, Commercial Interiors, Existing Buildings, Core & Shell, and Schools.

Table 1: LEED rating systems [11]

Credit	New Construction	Commercial Interiors	Existing Buildings	Core & Shell	Schools
Sustainable Sites	26	21	26	28	24
Water Efficiency	10	11	14	10	11
Energy and Atmosphere	35	37	35	37	33
Materials/Resources	14	14	10	13	13
Indoor Environmental Quality	15	17	15	12	19
Innovation in Design	6	6	6	6	6
Regional Priority	4	4	4	4	4
Points Total	110	110	110	110	110

At WPI, sustainability is becoming integrated into the design and construction process. WPI is striving to become a sustainability leader in its community by adopting a high performance, minimal impact approach. Currently, WPI has four LEED certified buildings which are the following [12]:

- Bartlett Center, 2006, LEED Certified
- East Hall, 2008, LEED Gold
- Sports and Recreation Center, 2012, LEED Gold
- Faraday Hall, 2013, LEED Gold

East Hall is the first sustainable residence hall on campus and the first to receive LEED Gold, features the city's first green roof. The residential hall used local and recycled materials, with an increase of energy and water efficiency, and includes an interior storage for bikes [13]. WPI's Sports and Recreation Center, constructed with recyclable building materials, features water-saving systems, solar energy, lighting sensors and controls, fritted glass, and rainwater harvesting [14]. Another example of WPI's interest of sustainability is its newly constructed parking garage/playing field. Even though it is not LEED certified, this structure provides 527 parking spaces with electric car plug-in stations, space for Zipcars, a bicycle parking area, motion sensors to dim/brighten lights, and a full sized athletic field on the roof.

2.5: LEED Energy and Atmosphere Overview

The LEED rating system has changed significantly over the years, with an increased emphasis on sustainable sites, water efficiency, and energy and atmosphere. Out of the seven categories, "energy and atmosphere" is considered to be one of the most important due to the large energy consumption and pollution generated by buildings. The mission of the energy and atmosphere category is to enhance energy performance by ensuring that mechanical systems, controls, and electrical systems are properly installed [11].

As previously mentioned, all LEED categories consist of prerequisites and credits. Prerequisites are required elements that are to be met before being considered for LEED certification. Credits are specific actions a project may take in the categories. Under the energy and atmosphere category there are three prerequisites and six credits.

Table 2: LEED Prerequisites and Credits

Energy & Atmosphere		**Points**
Prerequisites	Fundamental Commissioning of Building Systems	Required
	Minimum Energy Performance	Required
	Fundamental Refrigerant Management	Required
Credits	Optimize Energy Performance	1-19
	On-site Renewable Energy	1-7
	Enhanced Commissioning	2
	Enhanced Refrigerant Management	2
	Measurement & Verification	3
	Green Power	2

Table 2 is an example of the Energy and Atmosphere checklist for new construction and major renovations. Under this energy and atmosphere checklist there are thirty-five possible points.

Definitions of the prerequisites and credits are described below [11]:

- Prerequisites:
  - **Fundamental Commissioning of the Building Energy Systems**
    Verify that the building's energy related systems are installed, calibrated and perform according to the owner's project requirements, basis of design, and construction documents.
  - **Minimum Energy Performance**
    Establish the minimum level of energy efficiency for the proposed building and systems, according to current standards. These standards are referenced from ASHRAE 90. 1 2007 or state code.
  - **Fundamental Refrigerant Management**
    Reduce ozone depletion.
- Credits:
  - **Optimize Energy Performance**
    Increase levels of energy performance above the baseline from the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use.
  - **On-Site Renewable Energy**
    Increase levels of on-site renewable energy self-supply in order to reduce environmental and economic impacts associated with fossil fuel.

- **Enhanced Commissioning**
  Begin the commissioning process early in the design process and execute additional activities after systems performance verification is completed.
- **Enhanced Refrigerant Management**
  Reduce ozone depletion.
- **Measurement & Verification**
  Provide ongoing accountability of building energy consumption over time.
- **Green Power**
  Encourage developers to use grid-source, renewable energy technologies on a net zero pollution basis.

2.6: East Hall LEED Scorecard

This section describes how East Hall got LEED Gold Certification in detail. The overall scorecard is described as well as the Energy and Atmosphere Scorecard.

LEED Scorecard

East Hall, a residential building completed in 2008, acquired 44 out of 69 points in the LEED certificate evaluation, which is sufficient to achieve LEED Gold certification. Out of the 6 general categories, this project focused mainly on “Energy & Atmosphere” and “Indoor Environmental Quality” since the aim of this section is to identify the expectation of energy consumption in East Hall. Site selection, water efficiency, and innovation are not considered. The figure below shows the LEED scorecard. For detailed scorecard, see Appendix A.

LEED Facts

for New Construction (v2.2)

Certification awarded Jun 2009	
Gold	44
Sustainable sites	12/14
Water efficiency	4/5
Energy & atmosphere	7/17
Material & resources	7/13
Indoor environmental quality	10/15
Innovation	4/5

Figure 2: East Hall LEED Scorecard brief view

Energy and Atmosphere

East Hall scored a total of 7 out of 17 points in this category. These scores are presented below:

- Optimize energy performance: 5/10
- On-site renewable energy: 0/3
- Enhanced commissioning: 1/1
- Enhanced refrigerant management: 1/1
- Measurement and verification: 0/1
- Green power: 0/1

By definition, “Optimize Energy Performance” intends to “Achieve increasing levels of energy performance above the baseline in the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use” [15]. According to ASHRAE/IESNA Standard 90.1-2004, the minimum energy cost saving percentage for new buildings scoring 5/10 falls between 24.5% and 28%. East Hall scored no points for renewable energy, measurement and verification and green power, as those are not applied in the building design or construction process.

According to the designer of the building, Cannon Design, East Hall Reduced energy costs by more than 20% versus ASHRAE 90.1-2004 standard. Data are evaluated via energy modeling, from the BIM (Building Information Modeling) model created during the design of the building. According to the building strategy, East Hall considered the effect of sun shading. This strategy of designing the shape of windows provides vertical sun-shading on the west façade to optimize energy savings by minimizing solar heat gain and glare and provides horizontal sun-shading on the south and east façades to optimize energy savings [16].

Figure 3: East Hall—vertical sun-shading

Figure 4: East Hall—horizontal sun-shading

The estimated savings by using this design are shown below:

- Estimated cooling load reduction: 15 tons
- Value of reduced plant: $34,000
- Projected Yearly Energy Savings: $6,480

Lighting in the residential rooms includes two types for two different room designs:

- 2*26W compact fluorescent open downlights
- 1*26W compact fluorescent open downlight and 1*task ambient T5 fluorescent desk light with up/down component.

Both two types of lighting provide adequate ambient luminance at the bedroom entrance, wardrobe, and center. However, the first method requires the students to provide their own desk lamps but the second one does not. Thus, the overall power density is 0.53 watts/ft^2 for the first method, but introducing an incandescent task light will raise power density to 1.45 watts/ft^2, and the Power density for the second method is 0.57 watts/ft^2, which provides the best light coverage with the least amount of fixture.

Figure 5: East Hall lighting design type 1

Figure 6: East Hall lighting design type 2

Indoor Environmental Quality

The most important line items in this section are the "Controllability of Systems—Thermal Comfort" and "Thermal Comfort—Design," since these factors affect the HVAC system efficiency.

East Hall scored one point for Controllability of Thermal Systems, which requires providing individual comfort controls for 50% (minimum) of the building occupants to enable adjustments to suit individual task needs and preferences and providing comfort system controls for all shared multi-occupant spaces to enable adjustments to suit group needs and preferences. However, East Hall fails to 'provide a comfortable thermal environment that supports the productivity and well-being of building occupants', as this category does not pertain to its specific needs. This section is investigated by surveys to study the actual users' feedback on the system.

2.7: Energy sources at WPI

To evaluate the energy consumption of WPI's buildings it is important to know about the sources of energy used by WPI. Electricity and natural gas were examined, as these are the two major energy sources for the WPI campus.

Electricity

Electricity is essential to have in buildings as it powers appliances for cooking, heating, and entertainment. WPI receives its electricity from National Grid's substation on Faraday Street [17]. The Power House receives the electricity from National Grid and from here it is distributed among the buildings on the main campus.[1] Now on the main campus there are twenty-nine buildings/properties, and out of these, only twelve buildings are sub-metered, Appendix B. Buildings outside the main campus, such as East Hall and Founders Hall, have individual meters. WPI purchases electricity from Direct Energy, an independent energy supplier. The reason for this is that WPI as a community consumes large amounts of electricity, and therefore it is cheaper to buy as a commodity. WPI pays National Grid for the service of transporting the electricity through their

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[1] The Power House, or Power Plant, has the main meter of the main campus.

substations and power lines. In fiscal year 2013 (FY2013) WPI as a whole consumed 31,044,833kWH. A breakdown of the data relevant to electricity used by the main campus is provided below:[2]

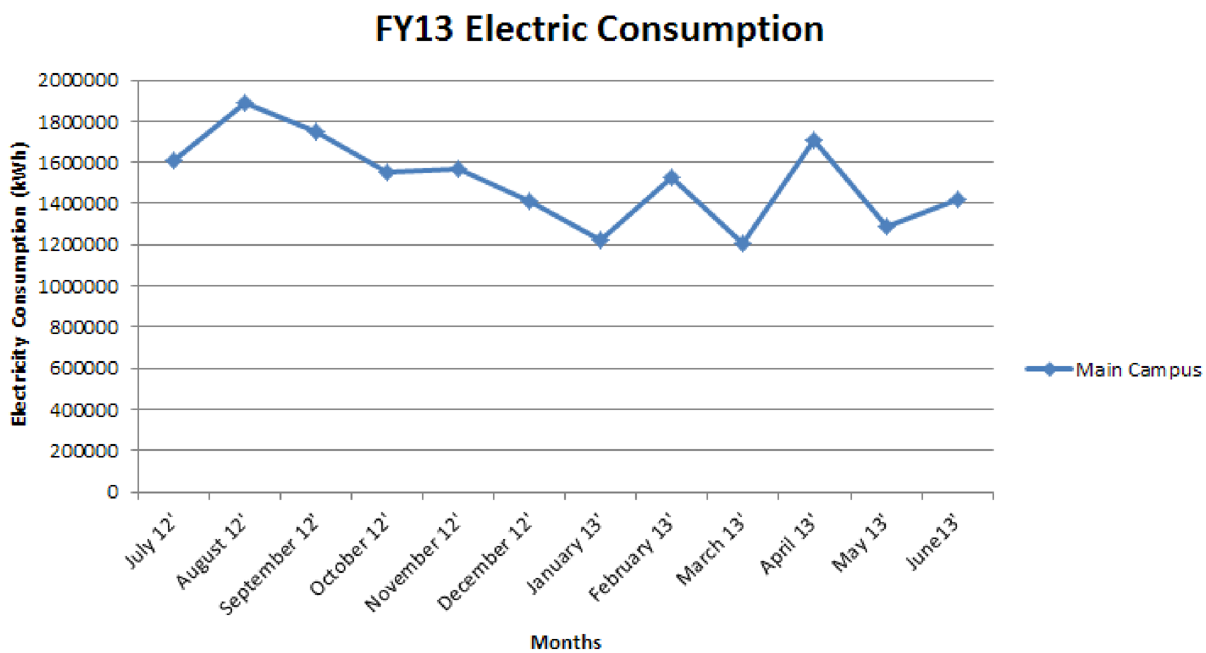

Figure 7: FY13 electricity consumption of the WPI Main Campus

In Figure 7, it is an interesting to note how the electricity consumption slowly decreases from August of 2012 to January of 2013 and then it spikes in February and April. The reason this is interesting is that during the months of December to February is all considered the winter season but yet in February the electric consumption spiked about 24% from January to February. Also April is another month that has an increase of 41% from March to April and then decreases 32% in May. We hope to investigate an explanation for this unusual trend.

Natural Gas

Natural gas, another important source of energy, is used to heat up our buildings and for cooking. WPI purchases its natural gas as a commodity from Hess Energy and receives its natural gas from NSTAR. The power house receives the natural gas and uses it to produce steam which provides heat to the buildings on the main campus. There is currently is one meter measuring the usage. On the main campus, there are twenty-four building/properties that are under this main meter, Appendix B. Again, buildings outside the main campus, such as East Hall and Founders Hall, have their individual meters. In the FY2013 WPI as a whole

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[2] The data is provided by Mr. Grudzinski, the Chief Engineer of the Power Plant.

consumed 1,521,885therms.[3] A break down detail of the main campus natural gas consumption is provided in Figure 8:

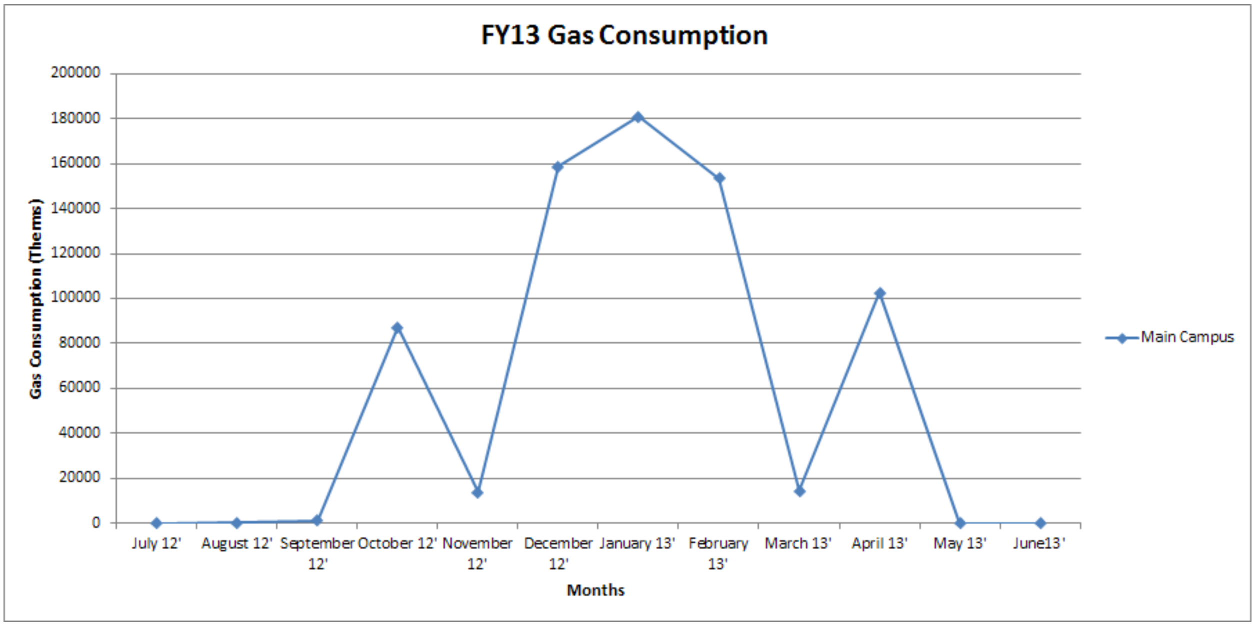


Figure 8: FY13 natural gas consumption of WPI Main Campus

2.8: Retrocommissioning and SynergE

As part of its efforts to transition to a more energy-efficient and sustainable campus, WPI has partnered with Clark University, College of the Holy Cross, National Grid, and GreenerU, Inc. to establish the SynergE Worcester initiative. Within this partnership, the three participating universities will collaborate with each other and National Grid to implement a multifaceted approach to increasing energy efficiency, reducing energy use, and promoting sustainability. The consulting company GreenerU, Inc. will facilitate this partnership. The multi-campus partnership puts endeavor to reduce energy waste and minimize carbon emissions through “innovative technical, financial, and human solutions.” The program will target energy efficiency installations that reduce fuel and utility costs for the schools; engage students, faculty, and staff in energy and sustainability initiatives; and utilize innovative financing to bring about reductions in energy consumption and greenhouse gas emissions [18].

In addition to promoting programs to engage community members to conserve energy, an effort will be undertaken to increase the efficiency of existing buildings on the three campuses, notably through the practice of retrocommissioning [17]. Retrocommissioning is the application to existing buildings of the commissioning process that is typically applied to new buildings [19]. Benefits of the retrocommissioning process include an improvement in the performance and operations of the building, as well as a potential cost savings due to increased efficiency.

[3] A unit of heat equivalent to 100,000 Btu or 1.055×10^8 joules

2.9: ENERGY STAR

ENERGY STAR, created by the United States Environmental Protection Agency (EPA), is a standard for energy efficient products adopted by several countries around the world. Consumer products that have the ENERGY STAR label consume up to 30% less energy than the federal standard [20]. John S. Hoffman, creator of the Green Programs at EPA, developed ENERGY STAR. It had originally begun as a labeling program that identified energy efficient products to promote and demonstrate the potential for profit in reducing energy consumption and greenhouse gases by power plants [21].

According to ENERGY STAR, there are many things that can be done immediately to conserve energy. When it comes to heating it is recommended that the air filter be changed because a dirty air filter slows down the airflow, making the system work harder. By changing the air filter often, dust and dirt do not accumulate and it prevents an expensive maintenance process in the future if the system fails altogether. Some of the simpler things that can go a long way are checking thermostat settings and sealing air ducts so that nothing is lost. If an air conditioning system is used during the summer it is important to keep every window sealed and limit the time doors are open. In the winter, ENERGY STAR recommends using a tight-fitting A/C unit cover to insulate the system properly from cold air getting in while the heating system is running [20].

ENERGY STAR Recommendations

WPI has many appliances in use around the entire campus. When doing laundry it is recommended to always wait to wash large loads because the washing and drying machines use the same amount of electricity regardless of the amount of clothes that are being washed. Also, it is best to use cold water and always clean the lint trap. In the apartments and kitchens around the campus a problem that arises is the wasted energy on stoves that have a pot on the wrong-sized burner. It a pot is too small compared to the burner there is heat energy lost there. Refrigerators are big appliances that draw a lot of electricity. To minimize the energy lost, the coils have to be clean, the door needs to be sealed properly, and the time the door remains open has to be limited [20].

Lighting and electronics are two things that many people do not realize have a big impact on the energy consumed by a building. In large buildings like those around the WPI campus there are many rooms that need to be lit properly. However, there are times when rooms are either over lit or do not need to be lit at all. An example of this is during bright days when natural light can be utilized or when rooms are completely empty. The best option to conserving energy on any electronic is to unplug it completely because anything that is plugged into an outlet continues to draw electricity. For students in the residence halls, TVs and gaming consoles are the biggest energy wasters. Power strips are helpful in conserving energy because when a TV or gaming console is not in use the power strip provides the option of cutting off the electricity provided to the electronics. Also, when watching movies on DVDs, using a gaming console consumes 4 to 7 times more power than a regular DVD player [20].

2.10: Building Information Modeling

Building Information Modeling (BIM) is a method of designing, modeling, and communication about a building. In contrast to paper methods, a BIM solution provides three dimensional, parametric models with information relating to the construction and operation of the building, including references to warranties and manuals. The object of BIM is to reduce communication and management complexity, to allow quicker turnaround for modeling, and to allow for easier and more consistent access to information regarding a building. Each component of the BIM model contains detailed information about that specific component. For example, when looking at a BIM model of a building, the user can see the pipes throughout the structure, what type of pipe, and even the size of the pipe. BIM has revolutionized the modeling world; where there was once a directory of components of a building, there is now an interactive model of an entire building containing all the same information [22]. BIM can prove to be helpful in improving energy efficiency through the systematic measurement and verification of building systems. The performance of a building or energy system can be evaluated through simulation. A BIM-based Baseline Building Model (B^3M) is created from an up-to-date BIM model. B^3M models can provide real-time simulation data on the performance of building systems and operating conditions [23]. BIM software allows to run simulations to supplement the sparse data available for the energy systems and to make rough estimates of the feasibility and benefits of any recommendation, and finally to identify energy saving or energy wasting components in the building.

Chapter 3: Methodology

In order to achieve the three goals related to energy efficiency for this project, stated in the introduction, the following steps were taken. First, some WPI buildings were selected and studied. Since there are over 50 buildings owned by WPI, it was quite difficult to investigate energy consumption in each building. As a result, some of the typical WPI buildings that reflect college feature (e.g. highly academic, student users) and energy saving strategies (ideally LEED certified) and that are comparable to each other were selected, to perform a case study. After target buildings were selected, surveys were sent to users of each building, in order to investigate behavioral attitudes and public opinion with regards to energy efficiency and consumption in those buildings. Energy audits were performed in each building to check the detail of possible physical issues of each building. Electric and gas meters of each building were monitored to continuously track the real-time energy consumption situation. Data acquired from these methods were collected and analyzed, and thus recommendations were drawn accordingly.

3.1: Building Selection

We focused on East Hall and Founders Hall. These buildings were chosen for investigation because they are among a small number of buildings for which separate electricity and gas consumption information is available. Founders Hall and East Hall are both residential buildings, fully occupied 24/7 during the academic year, and at a reduced occupancy during term breaks. Additionally East Hall was constructed in 2008 to meet the standards for LEED certification, while Founders Hall was constructed in 1985 under more traditional building methods. With this selection of buildings, we created a comparison of the efficiencies between the newer, LEED certified buildings with those of the older buildings on campus.

Figure 9: East Hall, LEED - Gold Certified

Figure 10: Founders Hall, Non-LEED Certified

Our selection of buildings does not include any primarily academic, office, or laboratory buildings on campus. This decision was made because none of the current academic or laboratory buildings was constructed recently enough to be LEED certified, and we wish to use the LEED certification as an axis on which to compare the buildings we are studying. Another reason for the decision was that previous IQPs had already addressed inefficiencies of some academic and laboratory buildings, including Higgins Laboratories and Atwater Kent, and they had already generated several suggestions concerning both heat and electricity. Finally, collecting energy consumption information for buildings on the main campus would be difficult as most of the buildings are supplied with electricity and steam from the Power House, and are generally not individually metered.

3.2: Building Comparison

While both East Hall and Founders Hall are residential buildings, they were built for very different use cases. Founders Hall, built in 1985, is composed of suite-style living accommodations, with suites for 1, 2, 4, and 6 residents living in single and double bedrooms sharing a common area and a bathroom. In the summer of 2013, the suites were outfitted with a refrigerator and microwave, and some double rooms were converted to triple rooms to allow for 8 residents in some suites. The residential areas are not cooled. Non-residential functions of the building include dining spaces—the Goat's Head Restaurant and the Outtakes Convenience Store—and the Campus Police station.

East Hall, built in 2008, includes student residences and office space for the Office of Residential Services. The residential spaces are 4-person apartment style suites. All suites contain singles, and some suites replace 2 of the single rooms with a double room. All occupied areas of this building are climate controlled by a continuously operating HVAC/ventilation system, which is controlled by a building management system. This building was built to LEED standards.

Both buildings include laundry facilities and external lighting.

Table 3: Comparison of East Hall and Founders Hall

	East Hall	Founders Hall
Year built	2008	1985
Total square footage	103,300	96,994
Maximum capacity	232	249
Non-residential functions	Res services/ID Office	Goat's Head/Outtakes/Police
Resident kitchen equipment	Refrigerator and stove	Refrigerator and microwave
Average monthly electric consumption (FY13)	95,133 kWh	60,796 kWh
Average monthly natural gas consumption (FY13)	2,893 therms	3,339 therms

From the table above, we see that the energy consumed by the two halls is very different while the capacity of residents is not too different. These buildings are also placed directly beside each other facing Boynton St.

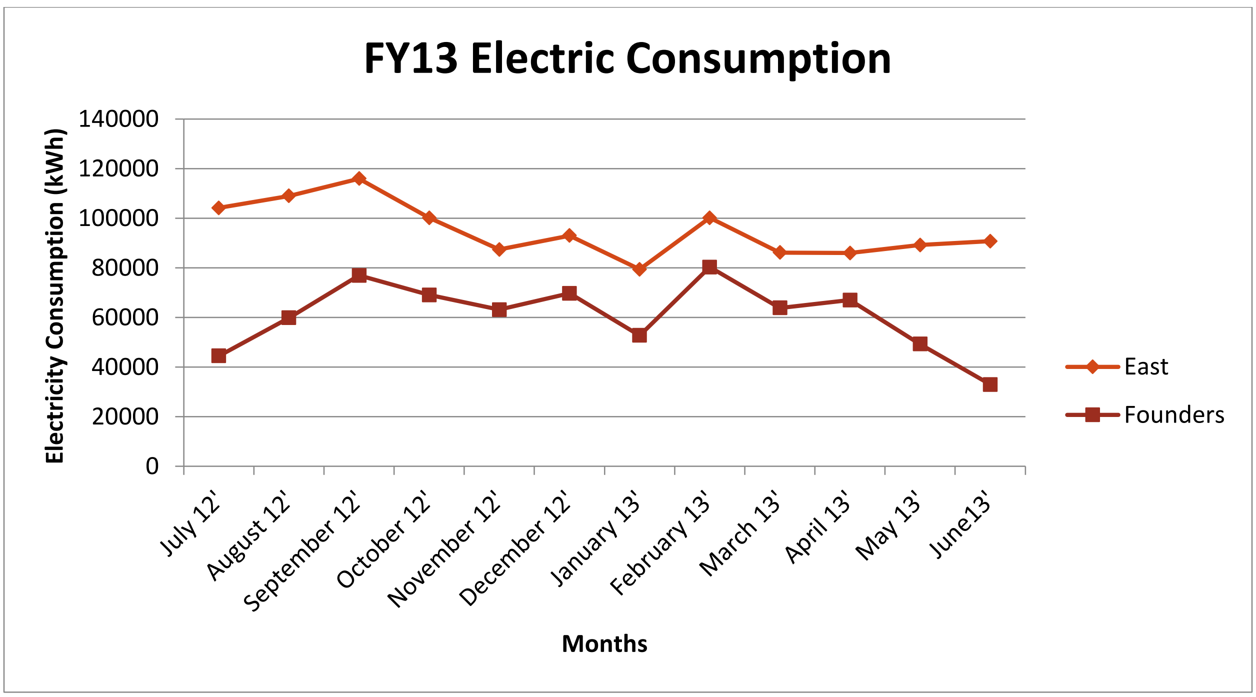


Figure 11: FY13 electricity consumption of Founders Hall and East Hall

East Hall is LEED certified and is supposed to operate at higher efficiency. However in Figure 11, it appears East Hall consumes more electricity than Founders Hall. Mr. Grudzinski, the Chief Engineer of the Power Plant, suggested that a reason for this is the air conditioning of the building in the summer. However, better explanation for the high usage in East Hall is important for the purpose of this study.

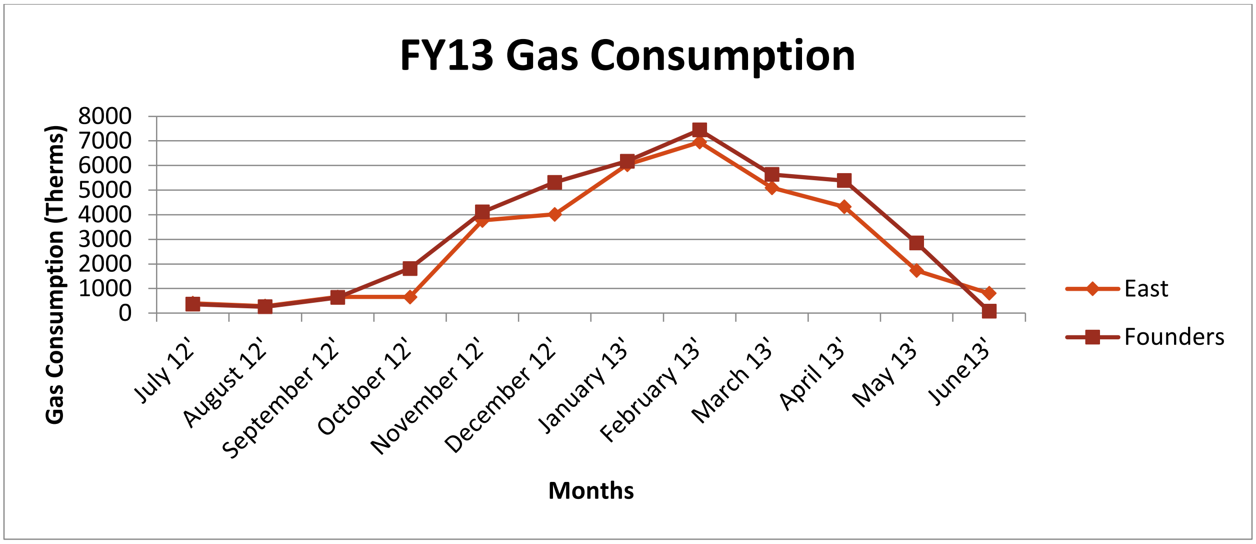


Figure 12: FY13 natural gas consumption of Founders Hall and East Hall

The natural gas consumption of both buildings are not so different, as shown in Figure 12. The trends are quite similar as both building consumption increases during the winter months, December to March.

3.3: Survey

Surveys are conducted to better understand the behavior of a specific group of people. In this project, the behavior of the residents needed to be better understood to be able to meet the third goal stated in the introduction.

How to Conduct a Survey

There are certain steps that a group or person conducting a survey must take in order to have a successful survey of their sample. The first step is to write a plan for the survey. This should include goals and objectives, the target population, the expected sample size, and the overall plan for the survey [24].

When putting together the actual survey, many things should be considered. The major thing that the surveyor must keep in mind is what he/she wants to learn from the survey. This includes appealing to a specific audience. For example, when writing the questions the most important thing to remember is: "Who is the audience?" Will the survey be about what kind of dessert the children of an elementary school wish to be served or will the survey ask the commuters on the Massachusetts Turnpike their opinion about their morning or afternoon commute? Two demographically different audiences require two surveys to be presented unique for the occasion. When ordering the questions on the survey, it is vital to rank the importance of each question that will be asked. The important questions should be asked earlier in the survey because the respondents may get fatigued or hurry when reaching the end. If possible or applicable, it can be very helpful to the researcher if the respondents are provided an opportunity to offer their own input either about the topic presented in the survey or the survey itself.

Qualtrics—Internet Survey Distribution

There are many advantages and disadvantages of distributing a survey through the Internet. First, it is not cost or time-effective to conduct a survey over the phone or by mail. Also, conducting a survey in person requires the control of many factors in order to get an unbiased response from the respondents. Examples of these factors are body language, tone of voice, and clarity in expressing the question. An Internet survey takes all of these factors out of the equation. It is much easier to create and distribute a survey using an internet source like Qualtrics. The major advantage in using an Internet survey is the collection, recording, organization, and analysis of the data. Qualtrics records all of the inputted answers and allows the user to graph and visually represent data. When targeting a population of 500, it can be very time-consuming and exhausting to manually have to go through cards or booklets and record data by hand to then input it into a spreadsheet. One of the various interesting features of Qualtrics is the ability to export the data recorded online to an Excel file, if a person is more accustomed to reading spreadsheets.

There are also many disadvantages of an internet survey. The biggest disadvantage is that there is no way to gauge the honesty of the respondents. In a case similar to this one where there is an incentive offered for a better response rate, there could be outlying subjects that provided dishonest responses on purpose. There are also surveys that require respondents to answer as quickly as possible, an example being psychological surveys in which a researcher is trying to determine a specific type of trend following stimuli. In that specific case, an internet survey is not ideal because the responder could take more time than is allotted because perhaps they want to get a correct answer. The problem is that this does not provide a very reliable result.

Therefore, the type of survey used has to be specific to the type of result that is desired.

Survey Goals and Expectations

The survey serves as an important approach to achieve the project goals—"To address behavioral issues of WPI constituency regarding attitudes toward energy consumption," and "to make recommendations on how to improve the efficiency and energy usage of all buildings on campus." Thus, the purpose of the survey is to probe the attitudes and behaviors of the residents on energy consumption. Two separate surveys were sent to residents in East Hall and Founders Hall in order to identify WPI students' consciousness towards energy consumption.

Through this survey, we hoped to address WPI's performance to build a comfortable campus and identify occupants' behavior in energy-saving aspects. Defects in WPI's heating/electric systems and behavioral issues that may affect energy efficiency were determined, thus providing specific fields that the IQP team focused on. Data on occupants' ideal situation (e.g. temperature) could be compared with that from the actual situation, and further calculation could indicate to what degree WPI could improve its energy efficiency in those particular parts, including heating system (heat, hot water), electric systems (lighting, other electronic devices), cooking, and occupants' behavior.

Survey Design

The survey was divided into four major blocks, each with its specific task goals, to fully study the behavior issue of the occupancy group. These four blocks include: demographic background, heating/cooling at WPI, electricity usage at WPI and human behavior.

Demographic Background

This section sought to identify the background information of the occupants. It enabled the IQP team to categorize the occupancy group in different ways, including floor number and building usage. Since people in different categories tend to have similar behavior (e.g. top floor usually complains about heating and opens windows), it would be very meaningful to differentiate people into different groups, and compare the behavior of each group rather than acquire a general overall data. Furthermore, data acquired from these questions introduced to the IQP team a general overview about WPI residents' awareness of energy saving strategies. These categories included:

1. Building, floor, and room identification, questions included:
   - What floor do you live on?
   - Do you live in a 2, 4, or 6 person suite?
2. User's familiarity of their room. This section sought to determine how well people are aware of the energy saving strategies in the building. People who are familiar with the building are defined as people who know how to properly utilize the energy saving features in each building. Questions included?
   - How long have you lived in the building?
   - Are you familiar with the energy saving feature in your building, like occupancy sensors?
   - Overall, do you consider yourself to be an efficient user of energy?
3. User's occupancy info regarding the expectation of the basic function of their room. This section categorizes people into groups that treat dorms differently, because some people like to study and entertain inside the dorm, causing more energy consumption while others may simply treat the dorm as a place to rest. Questions included:
   - On average, how much time do you spend per day (weekday/weekend) in your dorm?
   - How would you define the role of the dorm? (in terms of activities and hours, options include sleep, study, entertain, eating)

Answers to these questions introduced to the IQP team some basic information about occupancy, and helped to categorize the occupants, to make the results more reliable and comparable. For example, a person's electricity usage significantly depends on the factors like time he spent in the room and what he usually does in the room (e.g. sleeping only verses entertaining). Thus, it would be unreasonable to judge people's efficiency in energy usage by solely comparing their total energy usage. As a result, the demographic background part is introduced to avoid such mistake, by comparing people's behavior within each category.

Heating/Cooling

This section sought to identify and quantify occupants' opinions on WPI's energy usage in heating and cooling aspects. Through this, the IQP team hoped to determine whether WPI has provided a comfortable living space for occupants, and thus was able to better understand the occupants' level of satisfaction with their room. The purpose of inspecting residents' opinions about the heating/cooling system is to clearly determine people's expectation and WPI's current performance, and to see if energy waste exists (i.e. heating too high during winter, user can't control thermostat). Questions included:

1. Occupants' general opinion on the buildings:
   - Overall, do you consider East/Founders Hall to be energy efficient?
2. Occupants' general opinion on comfort level of the building
   - Considering Heating/AC system, do you feel comfortable during winter/summer?
   - Overall, do you consider East/Founders Hall to be a comfortable place to live?
3. Specific questions about heating system. In this section, heating in the room and hot water are considered the major users of the heating system in daily life. Questions in this section mainly focused on occupants' opinions and expectations regarding the heating systems, and through these

questions, the IQP team could determine whether WPI is providing insufficient, sufficient or overly sufficient (thus energy waste) heating. Questions were categorized as:

- People's opinion and behavior:
  - Is it too hot/cold in winter? (and summer for east hall)
  - If it is too hot, do you find need to open the windows? (If yes, then how often do you open the windows, and how long do you leave the windows open?)
  - How long it usually takes for the room to heat up to your desired temperature?
- People's expectations
  - What temperature do you set for heat in winter? (and AC in summer for east)
  - At what temperature do you feel comfortable in the winter?(and summer for East Hall)
- Occupants' control of the heating system
  - (open ended) Do you wish to have better control of the thermostats? Write down your suggestions.

Electricity

Similar to heat, this section asked about lighting and other electric appliances that affect energy consumption. Some major sources of daily electricity consumption are inspected, including lighting, refrigerators, cooking, and residents' personal electric appliances. The IQP team expected to check WPI's current performance in providing such fields to identify possible energy waste, and to understand the residents' basic need in electricity consumption. Questions included:

- Lighting
  - Is there sufficient interior lighting in your room?
  - Could you specify locations that are well-lit and that are not well-lit?
  - Do you feel need to use additional lighting (e.g. desk lamp)
  - Comments on lighting?
- Electric appliances and personal belongings
  - Do you use the fridge often and how full it is usually?
  - Do you own a TV/laptop/desktop/gaming system?
  - On average, how many hours a week do you use your TV/laptop/desktop/gaming system?
- Cooking
  - Do you cook in East/Founders Hall?
  - (if so) How often do you cook on a weekly basis?
  - What do you prefer to use to cook, microwave or stove?
  - Comments on cooking systems?

Human Behavior

This section looks more into the occupants' attitude and behavior aspects, and thus identifies aspects that people can improve to maximizing the energy efficiency.

1. People's consciousness about energy conservation
   - Attitude/awareness towards saving energy
     - Do you consider it's necessary that everyone should save energy?
2. On average, how much energy in kWh do you think you'll use? Write it down.(This question checks whether residents truly have a sense of their electricity usage)Personal habits

- Difference between home and school? (since bills are not charged on you)
- Personal habits that may cause energy waste.
- Do you usually tend to leave the following devices on when it is not being used? *(Here a list of electronics was provided, and the occupants were asked to check them off if applicable.)*
- Which electronics are plugged in at all times, regardless of being in use or not? *(Here a list of electronics was provided, and the occupants were asked to check them off if applicable.)*

Through these questions, the IQP team sought to identify possible energy waste caused by occupants' habits, and determine the possibility of improvement (by raising their consciousness about energy saving) and calculate how much energy could potentially be saved if people change their behavior. For the actual survey questions, check Appendix G and Appendix H

Survey Distribution

The targets of the survey are the resident students of East Hall and Founders Hall. The questions are specifically designed to get their true opinion of the residence hall in which they are living. This is important because the resident students are the ones that are most likely to provide suggestions for improvement on things that the staff that work in those buildings may not experience. For example, staff probably wouldn't know if there were a draft coming through a closed window during a cold winter night.

Recently WPI has changed their policy regarding email. In order to send an email to a mailing list, the email first has to be moderated by the Student Government Association (SGA). This makes it difficult for us because we wanted to get the survey out as quickly as possible. Our answer to this was to get the names of the Resident Advisors (RAs) of each of the floors of the two residence halls and send an email to them, asking them to distribute the surveys to their respective floors. The problem with this was that we were depending heavily on the RAs without knowing their disposition. In order to get as many responses as possible we wanted to offer an incentive for the students to take the survey. Our incentive was a $25 Dunkin Donuts gift card, which we gave to a randomly chosen person at the end of the survey. Our hope was that this would raise their interest in taking the survey since many people like to drink Dunkin Donuts.

3.4: Energy Audit

An important step in our investigation of the energy consumption in East and Founders Hall is to perform an energy audit. Energy audits are performed to determine how the building is consuming energy, this way it will help to make recommendation on improvements. Our energy audit consist of examining the building layout, review energy bills, perform walk-through audits, and collecting real-time data by recording the meter reading day-by-day.

Building Plans

To start an energy audit it is important to research and understand the physical background information of the buildings before conducting an energy audit. Building floor plans, buildings total square footage, number of occupants, residential room capacities, preinstalled appliances, non-residential functions, and monthly electric and gas consumption are important information we received from Residential Services and Facilities. This information not only helps us understand the operations of the buildings but also compare the buildings' intended functionality use, such as hosting shows, group projects in tech suites, or regular residential uses.

The floor plans of the buildings are essential tools for us to conduct an energy audit. The floor plan provides us with information such as room locations, relative room size, and the number of windows and entry and exit doors. While conducting the walk-through energy audit of East Hall and Founders Hall we used the building plans to record the data such as luminance reading, light bulb locations, the amount of light bulbs in certain locations, HVAC vent and air handler locations, and any present drafts. With this information on the floor plans it helped us compare the lighting systems (bulb types, luminance reading, and locations), HVAC locations, Founders Hall heaters locations, windows sizes, windows functions (if it opens or its fixed shut), and areas with a present draft. The Department of Facilities and Professor Guillermo Salazar provided the building floor plans for East Hall and Founders Hall presented in Appendix I.

Energy Bills

Collecting data of the buildings electric and gas usage from the last 12 months is a handy tool for the audit. We found this information by using WPI's bill from NSTAR (gas) and National Grid (electric) as it presents the usage history of the buildings. The reason why it was important to collect the building electric and gas usage was to get an overall picture of the building electric and gas consumption history. We were able to see trends of the electric and gas consumption such as what is the consumption difference from each of the winter months and summer months. Another reason to collect the buildings usage history was to compare East Hall and Founders Hall to one another by dividing the total consumption (gas or electric) to the square footage of the buildings.

$$\frac{Total\ Energy\ Consumption}{Buildings\ Square\ foot}$$

With this data, we were able to compare how much energy is used in a square foot. This is important data because it compared a LEED certified building (East Hall) to a non-LEED certified building (Founders Hall). Comparing them we examined how effective the energy efficiency of a LEED certified building is to that of a non-LEED certified building.

Walk-through Audit

A walk-through energy audit consists of touring a building to identify any obvious inefficient components and practices. Steps in this process include taking an inventory of the electric and heating systems in the building, and evaluating the building envelope. An invaluable resource in conducting the walkthrough audits is the *Commercial Energy Auditing Reference Handbook* [25], which includes energy saving opportunities by building type, as well as data on common types of lighting and mechanical systems.

The inventory process consisted of a few stages. The first stage was to obtain access to all areas of the building, by working with the Department of Facilities and the various occupants of the space. The next step was to inventory the lights and permanent appliances and to evaluate the heating and cooling systems. Part of the lighting inventory was to take luminance readings using a lux meter. Finally, the building envelope was evaluated, including taking measurements of windows and locating areas of noticeable draft.

Metering

Monitoring the energy usage of electricity and gas, in East Hall and Founders Hall was an important step in the energy audit. The monitoring gave us a sense of how much energy the building consumes on a daily basis. While monitoring the meters on a daily basis we also took into account the temperature, its highs and lows.

Recording the high and low temperature of the days gave us a sense of how the outside temperature correlates to the amount of energy the building is consuming. The process of energy monitoring consisted of visiting East Hall and Founders Hall meters every morning at a relatively similar time and either record the data by hand or take a photo with a smartphone, then transfer the data to the meter tracking sheet (see Appendix C), and then break down the data into a graph form and view the day to day trends. We started reading the meters on December 2 and ended on December 20. WPI's winter break went from December 19 to January 16. Upon returning to classes on January 16 the meter reading was resumed for that one day. With this information we were able to compare the difference in energy consumption with the buildings regular operations with residents to without residents.

Initially this process sounded simple but we did run into some obstacles. The meters for East Hall are located outside by the northern side of the building, Founders hall on the other hand has its gas meters located outside and the electric meter in the basement, which is where the WPI police station is located. To get access to the Founders electric meter we needed to be accompanied by our IQP advisor and escorted by an officer to the room where the electric meter is located. Rather than going through that struggle each time we decided to place a computer and webcam set-up to view the meter, Figure 24. The setup consisted of a computer tower, a webcam on top of a tripod facing the meter, an LED light, and a power outlet timer that will control the light. The process of monitoring this meter is to remotely access the computer from a personal computer or smartphone in the morning from 7:15am to 8:15am (we set-up the light timer and the computer to turn on at 7:15am and turn off at 8:15am). After logging into the computer we accessed the webcam to view the meter and record its data.

Chapter 4: Results

This section presents and describes the results of all parts of the project.

4.1: Survey Results

Here the surveys were analyzed and discussed in detail. The following section presents the responses provided by the residents of East Hall and Founders Hall. These responses can also be seen in Appendix G and Appendix H, as well as Table 4: East Hall/Founders Hall Survey Questions.

Overview of survey results of East Hall and Founders Hall

Here presents a general overview of survey responses for East Hall and Founders Hall.

Table 4: East Hall/Founders Hall Survey Questions brief overview

Question	East Hall key response	Founders Hall key response
1. How many people are there in your suite?	96% said 4	45% said 4, 55% said 6
2. How long have you been living in East/Founders Hall?	57% less than 1 year, 43% at least one year	95% less than one year
3. Overall, do you consider yourself to be an efficient user of energy?	9% yes, 74% somewhat	24%yes, 48% somewhat
4. On average, how many hours do you spend in East/Founders Hall each day?	13 on weekday, 15.5 on weekend	13.3 on weekday, 15.8 on weekend
5. How would you define the role of the dorm?	Mostly rest, studying entertaining, dinging (over 70%)	Mostly rest and studying
6. Overall, do you consider East/Founders Hall to be energy efficient?	70% Yes	10% Yes, 50% No
7. Overall, do you consider East/Founders Hall to be a comfortable place to live?	74% Yes	80% Yes

Table 5: East Hall/Founders Hall Survey Questions brief overview (continued)

Question	East Hall key response	Founders Hall key response
8. Considering the AC in room, how do you feel during summer? (East Only)	48% comfortable, 35% somewhat hot	
9. Considering the heating in the room, how do you feel during winter?	48% comfortable, 35% somewhat hot	55% comfortable, 25% somewhat hot
10. Have you ever opened the windows during the winter due to overheating in your room?	39% Yes	45% Yes
11. How often do you have to open the windows due to overheating?(if answered Yes in previous question)	63% less than once a week	71% less than once a week
12. How long do you usually leave the windows open?	25% less than 1 hour, 75% longer	75% less than 1 hour
13. When your windows are closed, do you feel a draft?	25% more than 'Sometimes'	75% more than 'Sometimes'
14. What temperature do you set for the heat in the winter?	71.3	70.6
15. At what temperature do you feel comfortable in the winter?	70.4	70.2
16. Do you have sufficient lighting in your suite?	25% No	56% No
17. Do you feel the need to use additional lighting anywhere in your suite?	35% Yes	75% Yes
18. Do you consider it necessary that everyone should save energy?	60% Yes	84% Yes

Some key comments include:

- East Hall:
    - “I've had difficulty controlling the thermostat - it seems like it doesn't actually do anything, and opening/closing the windows didn't have any effect on the AC”
    - “I would like to be able to turn off the A/C. One morning the sun was shining on the thermostat so the A/C was blasting and we were cold. We had to open a window to the colder outside air to get the A/C to turn off. Also, when we're all home and in our rooms working for several hours the heat will turn off because and we sometimes get cold.”
    - “The suite heats unevenly. My room terms to be chilly while the double is pretty warm.”
    - “There is no heat, the air coming out of the vents are cold. The thermostat read 64 degrees this morning.”
    - “Kitchen needs more light at night.”
    - (regarding comments on lighting) “Location, my head creates a constant shadow on my desk when working. there is also no lighting by the door or by the counter”
- Founders Hall:
    - “The thermostat will often read a higher temperature than it actually is. If we set it to 70 it will turn off around 65 because it reads 70. Also because of the draft in the personal rooms, the rooms will be colder than the common room where the thermostat is.”
    - “I wish we could control the bedrooms separately.”
    - (regarding heating system) “ think it works great, just wish there was more control for individual rooms”
    - “My light is located directly above the closet, and I do not have a built in desk-light.”
    - “The rooms only have one light that's too harsh, so I usually use a lamp instead.”

Founders Hall

A total of 22 Founders Hall residents responded to the survey we distributed. With 230 residents total residing in Founders Hall, this gives us a 9.5% response rate. The response rate matches the average response rate of US citizens towards a standard public survey, which is around 10% in year 2012 [26]. This response rate is acceptable, but more engagement of student is required for a much representative data. Ways to increase the response rate include increasing the gift card value, and sitting face to face with students in each hall. 83% of the surveys were completed, answering each question. Since one of the questions were "How long have you been living in Founders Hall?" we found that only 9% of the respondents have been living in Founders Hall for more than one academic year. This means that the other 91% of respondents have been living in Founders Hall for less than one academic year. Those who consider themselves energy efficient are only 23%, while those who do not consider themselves energy efficient are 27%. The other 50% considered themselves somewhat efficient users of energy.

In Founders Hall, 100% said they use their dormitory for resting and sleeping, 82% said they use their dormitory for studying, and 59% use their dormitory for entertainment and dining. During the five weekdays, the average amount of time spent in Founders Hall was 13 hours. During the weekend, the average amount of time spent in Founders Hall was 16 hours. It was expected that residents would generally spend more time in their dormitory during the weekend because there are no classes and most students like to sleep in on both Saturday and Sunday. Those who consider Founders Hall to be a comfortable place to live amount to 76% and those who consider Founders Hall somewhat comfortable are 24%. There were none who said Founders Hall was not a comfortable place to live.

The next part of the survey was regarding the heating in the rooms. During the winter, 29% said they were somewhat hot, 52% said they were comfortable, 14% said they were somewhat cold, and 5% said they were cold. Of those that were somewhat hot, none lived on the fourth floor of Founders Hall, 17% lived on the third floor, 50% lived on the second floor, and the remaining 33% lived on the first floor. This turned out to be a different result from what we had originally expected because our original expectation was that the higher floors would be warmer, but these results disprove our hypothesis. Of those that said they were either cold or somewhat cold, 100% said there was a draft coming through their closed window. Overall, 50% said they felt a draft come through their windows. The survey provided a section for any comments about the residents' satisfaction or dissatisfaction with the heating system. One of the themes that were commented on more than once was the dissatisfaction with the fact that there was only one thermostat to control the heat of the entire suite located in the common area. Overall, the residents of Founders Hall would like to have more control over the temperature variation in their individual bedrooms. They would like to have one thermostat in each bedroom instead of just one thermostat located in the common area because the temperature in the common area does not translate well to the temperature in the bedrooms. There is also a difference between the temperature in the single bedrooms and the temperature in the double bedrooms. One of the comments stated that the singles get very warm while the doubles do not heat up to the same level.

Another part of the survey was concerned with the lighting of Founders Hall. 42% of the residents said they had sufficient lighting in their suite 58% said they did not. This section also provided the opportunity for residents to comment on their satisfaction or dissatisfaction with the lighting. Common statements are that the closet area is well but not the other side of the bedrooms. The same situation is present in the common area: only one side is well lit, the other is not.

The survey asked questions about how often the residents used the refrigerator provided in the suite. 15% said they never open the fridge, 65% open the fridge 1-2 times a day and 20% open the fridge 3-5 times a day. Of those who never open the fridge, 33% said their fridge was full and 67% said their fridge was half full. Of those who open their fridge 1-2 times a day, 38% have a full fridge and 62% have a half full fridge. Finally, of those who open their fridge 3-5 times a day, 25% have a full fridge and 75% have a half full fridge. Originally we expected the correlation between how full a fridge is and how many times a person opened to be directly proportional, but this was not what the results showed. 65% of the people who do open their fridge anywhere from 1-5 times a day, had a half full fridge, the other 35% were the ones that had a full fridge.

In the final part of the survey, we asked the residents of Founders Hall if they considered it necessary that everyone should conserve energy. The results were: 80% said yes, 10% said no, and 10% said they don't care. Of those that said yes, 47% leave their laptop on, 6% leave their desktop computer on, and 25% leave their lights on. Of those that said no, 50% leave their laptop computer on but they do not leave any other devices on. Of those that said they do not care, 100% leave their laptop, desktop computer, and televisions on, and 50% leave their lights on. From these results we see that the residents of Founders Hall that do not care whether we should conserve energy or not have the highest percentage among themselves of leaving electronics on.

East Hall

The survey for the East Hall took the same format as the one for Founders Hall.

A total of 24 East Hall residents responded to the survey posted. The response rate is 10.3%, similar to that of Founders Hall. As has been mentioned, more engagement of student is required. Among the 24 students who took part, 10 of them were residents for longer than 1 year. This survey provided a good test as to how long-term residents felt about East Hall's sustainable features.

Although 43% of students who took the survey have resided in East Hall for more than 1 year, only 17% were confident that they are familiar with the energy saving features in East Hall, and 9% considered themselves an efficient user of energy while most residents – around 70%, showed their recognition to these questions as "somewhat familiar" or "somehow", which indicates that in general, WPI residents' have an opaque impression in these fields. 70% of the students consider East Hall to be energy efficient, and 76% of the students said that East Hall is a comfortable place to live, indicating a high satisfaction level of the living conditions of East Hall. On average, residents spend 13 hours in their dorm during weekdays, and 16 hours during the weekend, including sleeping time. 83% also defined the role of the dorm as for studying, 74% as a place for entertaining, and 74% as a place for dining including cooking.

Regarding the cooling system in summer, 48% felt comfortable about the AC supply during summer, and 35% felt somewhat cold. The range available for the thermostat is set from 69 to 72 degrees, while on average people consider 69.7 degree as a comfortable temperature.

26% felt comfortable about the heating in winter, 26% felt somewhat cold and 47% felt cold. Due to the limitation of respondent group, analysis of heating system according to floor is not performed. On average people set 71 degrees for the thermostat. Among those people who felt cold, 70% never opened windows in winter and 70% agreed that the windows are well sealed. Among people who felt hot, half opened windows during winter, and 40% of them left windows open all the time. Comments about the Heating/Cooling system are mainly about the control of the thermostat.

75% felt there is sufficient interior lighting and 65% said they do not require additional lighting. Most of the respondents said kitchen needs more lighting, and some of them need desk lights. One comment stated that the improper placement of lighting constantly creates a shadow.

Upon the question asking about residents' estimation about their daily energy usage in kWh, almost all answered no idea or gave false estimation. This could potentially imply that most residents don't have a sense of energy and power used by each device, which may cause problems towards energy conserving. For example, many people know turning off lights is a great way to save energy, while they tend to ignore "minor" issues like leaving hairdryers on or overheating using microwave since these issues stay only for a few minutes. Nevertheless, due to the high power of these devices, actually tremendous energy is wasted in these processes. Energy wasted by leaving a hairdryer on for a minute approximately equals that wasted by leaving a light on for an hour.

60% considered it necessary to save energy, while 10% said no and 30% they don't care about energy waste. Among people who said "Yes," 92% rarely or never open their windows. Apart from TV, and device charger (which may not be easy to unplug), most easy-access devices are unplugged (60% to 75% due to different device) when they are not used. Among those who answered No or I don't care, 50% opened windows. People in this group are more likely to leave devices on (about 10% higher on most cases).

Summary of Survey for East Hall and Founders Hall

Findings from Survey

Based on the response from the survey, comparison between two buildings and some shortcomings of building design is discovered:

1. Generally residences agree that East Hall is relatively more energy efficient than Founders Hall according to their using experience and most of them are satisfied with the living condition in both halls.
2. East Hall performs better at insulation in windows, and lighting levels than Founders hall. 75% of residents in Founders Hall feel a draft in the windows more than 'sometimes', indicating a potentially great amount of heat leakage. More than half of the residents in Founders Hall aren't satisfied with the lighting level and 75% mentioned the requirement of additional light. Comments provided by the residences show that such a problem is mostly caused by improper placement of lighting, which causes shadows, and thus energy inefficiency. Furthermore, the personal lighting devices brought in by residents may not be as efficient as those provided by WPI. These problems are confirmed by the energy audit later in this report. For details of the survey results, check Appendix G.
3. The residents of both East Hall and Founders Hall have difficulty controlling the heat. For East Hall, as has been commented by many residents, the thermostat doesn't seem to perform well, and change in room temperature doesn't have much effect on the thermoset. For Founders Hall, comments indicate that residents are relatively satisfied with the sensitivity of the thermostat; nevertheless, they need separate control of heat in each bedroom instead of a general thermoset for the whole suite. In both cases, people sometimes have to open windows due to overheating, either because of insufficient control of heating system or other people's choice of preferred temperature. In both

halls, around 40% of residents open windows during heating season and 75% in East Hall open windows for longer than one hour, showing significant energy loss.

Attitude and Behavior

Overall, WPI students are concerned about conserving energy. Regarding the question “do you consider it necessary that everyone should save energy”, over 70% respondents answered “Yes.” This number still needs to be improved, as WPI is devoting its effort into making a more sustainable campus, and students’ support is vital.

In order to study whether user attitudes affect their daily behavior, the following chart was created according to the feedback from the survey.

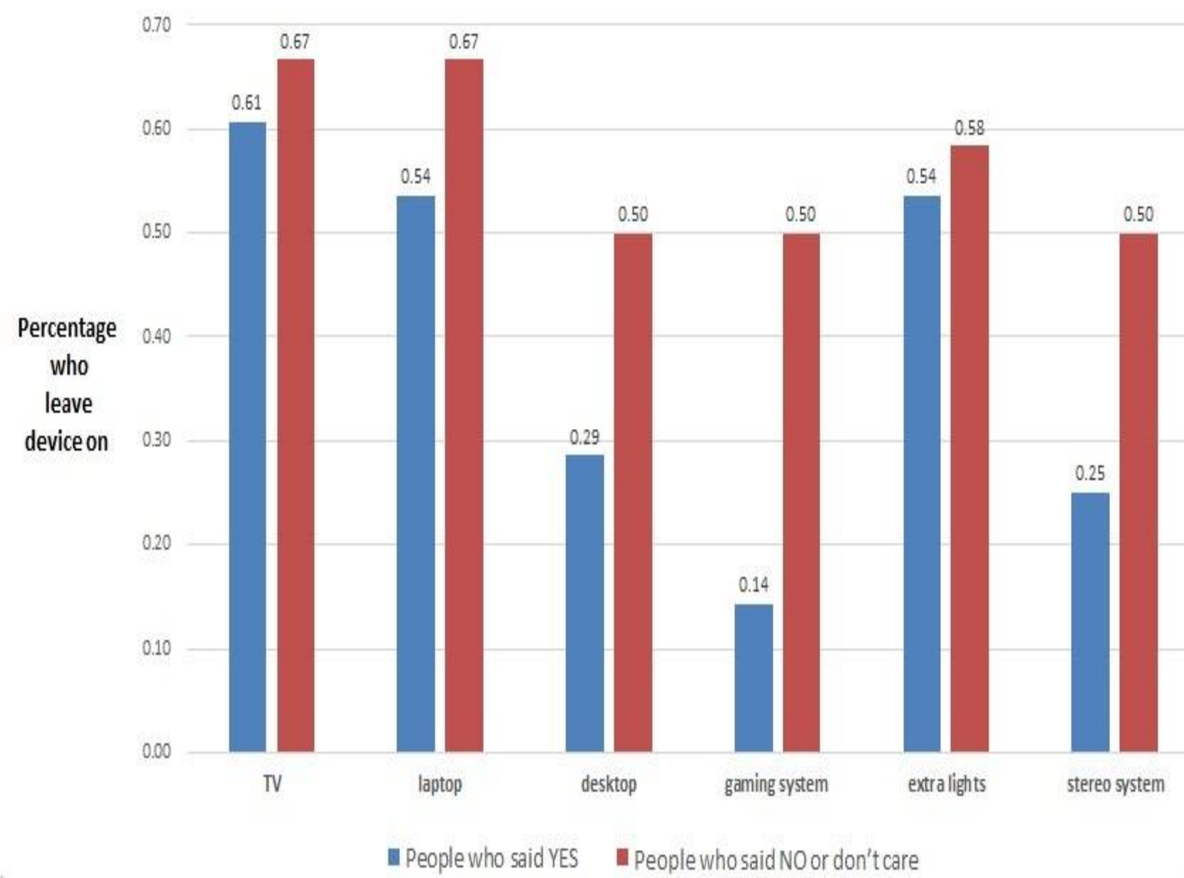


Figure 13: Comparison of people with different attitudes

The figure offers a direct comparison between the behaviors of people who have positive attitude towards conserving energy (marked in blue bar) and those who have negative attitude (red bar). From the chart, it can be said that in general, people who care about conserving energy are less likely to leave devices on (4% to 36% less in each case). For more detail, see Appendix G and Appendix H. One of the findings is that the difference in devices that are very often used like TV or laptop is very small, while the differences in devices that are less often used like stereo system and gaming system is quite large. This may be because some devices are so often used that for convenience, people seldom unplug them. The table below shows the cost of leaving each device on. The data for each device's idle power is acquired from Lawrence Berkeley National Lab [27].

Table 6: Idle power of devices

Device Name	Average Power when idle (W)	Energy wasted per day (kWh)	Money wasted per day (¢)
Charger, mobile phone	2.24	0.053	0.70
Computer Display	0.8	0.019	0.25
Desktop	2.84	0.068	0.89
Laptop	4.42	0.106	1.37
Printer	1.26	0.030	0.39
Stereo system	1.66	0.040	0.52
TV	3.06	0.073	0.93
Game console	1.01	0.024	0.32

Notice that the unit for money wasted is in cents. The way to calculate the cost for electricity per kWh will be discussed in detail later in the report. Even though the power and the cost seem to be small per person per day, they do add up to a huge amount. A man wastes 5.22 kWh per month if he leaves only laptop and desktop on all the time.

Residential Services Office

A total of ten people responded to the Residential Services Office survey. Although the exact response rate is not clear because they did not disclose with us exactly how many employees work in the Residential Services Office, we do know that this is a much higher response rate than those of East Hall and Founders Hall.

Of the ten people that did respond to the survey, only nine were primarily located in the Residential Services Office in East Hall. Of those who did primarily work in East Hall, 56% were full-time employees and 44% were student workers. The average time spent in East Hall for work was six hours a day during the week, and 2.5 hours a day during the weekend.

When asked how familiar they were with the energy saving features of East Hall, 33% said they were very familiar, 44% said they were somewhat familiar, and 22% said they were not familiar. 44% considered East Hall to be an energy efficient building while 56% said they were not sure. None of the employees said East Hall not energy efficient. Only 22% of the employees considered themselves to be efficient users of energy at work, 56% said they were somewhat efficient users of energy, and 22% honestly considered themselves not efficient users of energy.

The employees were unanimous in saying that East Hall was comfortable in the summer, but they were divided when asked how the temperature was in East Hall during the winter. 22% said it was very cold, 67% said it was somewhat cold, and only 11% said it was comfortable. Although the majority of employees in the Residential Services Office felt cold in the winter, only one person said they could control the heating and AC in the office. When asked to comment on their satisfaction or dissatisfaction with the heating and cooling system in the office, one person wrote: "I hate that the vent blows all day. MY office is freezing during the winter. It is so uncomfortable to the point I have to wear a blanket all day or trick the thermostat into reading that I need more heat."

When asked if there is sufficient lighting in their office, 89% of the employees said yes and 11% said no. In the same manner, and as expected, there was a direct correlation between those who said there was not sufficient lighting in their office and those who said they felt the need to use additional lighting in their workspace. The results were actually identical with 11% saying they needed additional lighting and 89% saying they did not. When asked to comment on their satisfaction or dissatisfaction with the lighting, more than one person said they would prefer lights that were not the typical fluorescent bulbs.

The next part of the survey asked about the different devices that were used in the office by the employees. 22% said they had a laptop computer, 100% said they had a desktop computer, 56% said they had a printer, 11% said they had a fan, 56% said they had device chargers, 22% said they had desk lighting, and 56% said they had a second computer monitor. When asked if they considered it necessary that everyone conserve energy 89% responded yes and 11% responded no.

Overall, in the Residential Services Office located in East Hall, it is safe to say that the majority is satisfied with their workspace except for only a very small number of people. Also, 77% are either very familiar or somewhat familiar of the energy saving features already implemented in East Hall. There were far less complaints from the Residential Services Office than from the students of East Hall and Founders Hall. This can be attributed to the amount of time spent in the respective places and also the familiarity of the respective buildings.

4.2: Energy Audit

Walk through audits were conducted throughout East Hall and Founders Hall. Areas audited include the common areas, such as hallways, lobbies, and common rooms, the mechanical and building service rooms, the Campus Police station in Founders Hall, and a representative residential suite in each of the buildings.

East Hall

In East Hall, we found most of the lighting is compact fluorescent (CFL) or a mix of T5 and T8 fluorescent lighting, depending on the location. However, both the north and south elevators were lit with small, incandescent lights. The wasted energy here is likely small, as the illuminance in the room was between 150–225 lux. In the trash room on the first floor, we found a significant draft coming from the door to the outside, resulting from an incomplete seal around the door, as illustrated in Figure 15. In this picture, there is an air blower blowing hot air in front of the door; further analysis correlation with plans should show whether this is an air curtain (to improve the building envelope) or a heating unit (likely wasting heat to the outside).

Figure 14: A T8 bulb used in East Hall

The residential areas in East Hall are lit with 24W compact fluorescent bulbs. The lighting levels are generally adequate in the residential suites, with lux levels ranging from approximately 80-365. It is to be noted that these lighting levels were measured with all lights in the suite turned on. During the walkthrough audit, it was discovered that the built in table in the four-singles suite was not directly lit, but was illuminated with lights in adjacent areas, namely the kitchen and the common area.

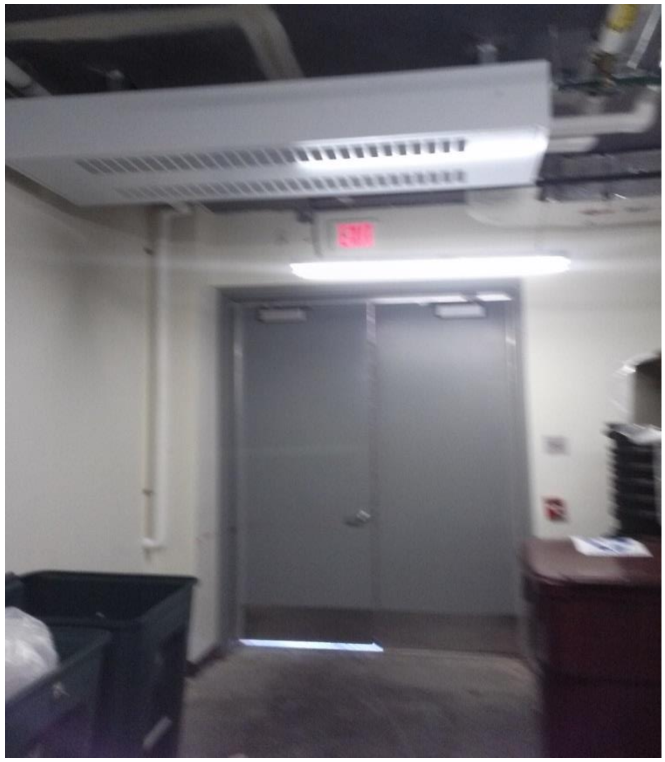


Figure 15: Gap in East Hall Main Trash Room door

Founders Hall

Most of the Founders hall basement is lit by T8 bulbs. One significant result of the initial Founders Hall walk-through audit was a complaint by a campus police officer that the Officer Work Room (room 105) is uncomfortably bright. This room is lit by U-shaped fluorescent lights, a lighting choice unique to the Campus Police Station, and illuminance levels are in excess of 600 lux at eye-level at the workstations. This area is in need of having its lighting reduced, both to increase building efficiency and occupant comfort.

The common areas and hallways in the residential portions of the building are also lit by T8 fluorescent lights. The lighting in the residential hallways averaged between 17 to 100 lux. Compared to East Hall and the basement of Founders hall, this is relatively dark. It appears the lack of lighting is due to the poor placement of the lights in the hallway: the light fixtures were placed perpendicular to the direction of the hall, creating uneven and inadequate lighting.

This trend of inadequate lighting extended into the suites. Of particular note is the bedroom lighting. Both the double and single bedrooms were lit by a single T8 light hung above the door of a built-in closet. This closet was generally across the room from the desk and bed. This resulted in uneven lighting, ranging from upwards of 300 lux near the closet, to as little as 5 lux at working height on the desk. The remainder of the suite averaged between 150 and 300 lumens.

The heating in the residential suites of Founders Hall is locally controlled, with each suite containing a Honeywell Round thermostat that allows the temperature to be set between 50 and 80 degrees Fahrenheit.

4.3: Metering

From December 2-20 and January 16 we monitored the electric and gas meters for East and Founders Hall. During this period of time we recorded the data and the temperatures. Founders Hall has two gas meters, one for The Goats Head Restaurant and the other is for the rest of the building, shown in Figure 16. With this setup it helped to distinguish how much gas is consumed by the Goat's Head Restaurant compared to the rest of the building.

Figure 16: Founders Hall Gas Meters

Figure 17 represents the amount of gas consumed by each building on a daily basis and the temperature. An interesting observation is the on December 16-17, East Hall consumed 619 therms and on December 18 -19 was relatively low, 24 therms. A Possible hypothesis to this is that it might be a glitch in the system. Analyzing this data, it is visible that there is a correlation between the outside temperatures and the gas consumption of both buildings. From December 2 to 8 the temperature was relatively warm and the consumption was low. The gas consumption starts to slowly rise on December 8-9 as the temperature drops. This makes sense because the gas is used as a heating and hot water systems of East Hall and Founders Hall. What is very interesting about East Hall is that it consumes just about the same as Founders Hall except for 5 days. This is important because East Hall, a LEED certified building, should not be consuming as much as Founders especially since it has newer energy efficient water heaters.

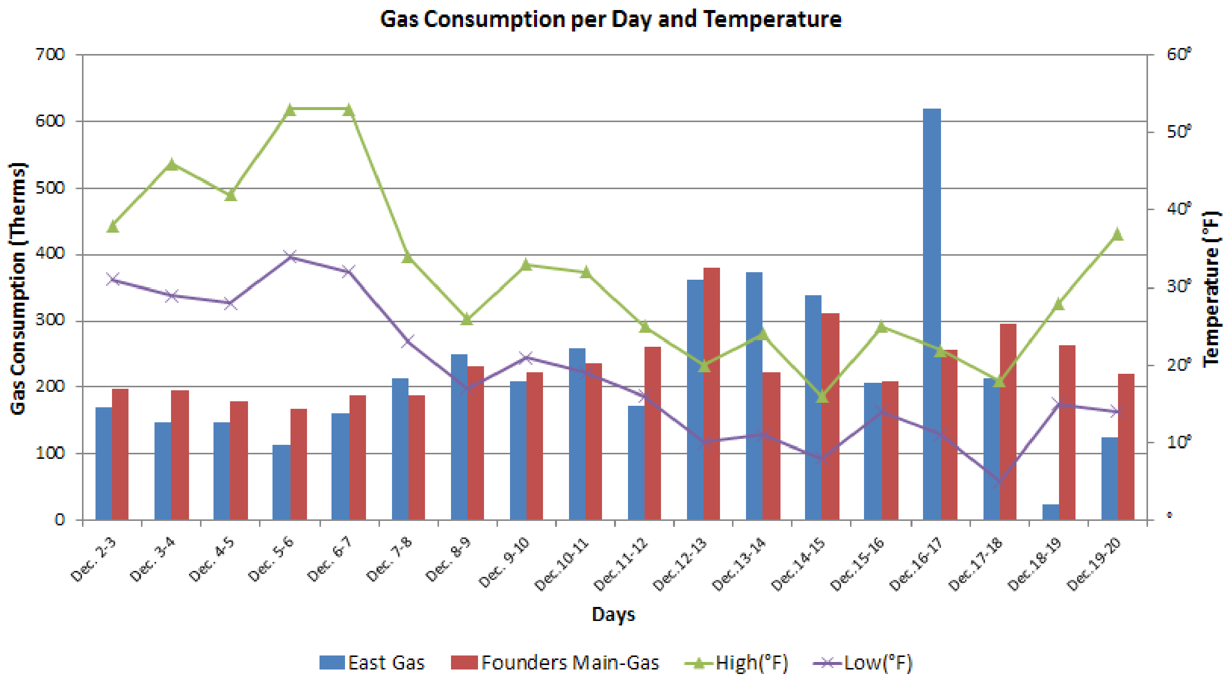


Figure 17: Gas consumption per day from December 2 to December 20

Now to break this down even further using degree days is another tool to help understand daily usage. Degree days is a measurement of approximately how many degrees it is needed to heat or cool the building of the day and allows us to make comparisons to previous months or years. Figure 18 presents the gas consumption per degree days, noticing the trends both buildings fluctuate quite a bit but Founders Hall has 11 days in which it is higher than East Hall. To examine and compare the building even further, Figure 18 represents the gas consumption per degree day per square footage of each building. Now this is a great way to investigate how much energy it takes to heat up a square foot. What is extremely surprising from the results is that East and Founders are not far apart. Founders Hall, a 29-year-old building, is using just about the same amount of energy to heat up a square foot as the 6 year old East Hall. This represents that East is not so efficient with its gas consumption.

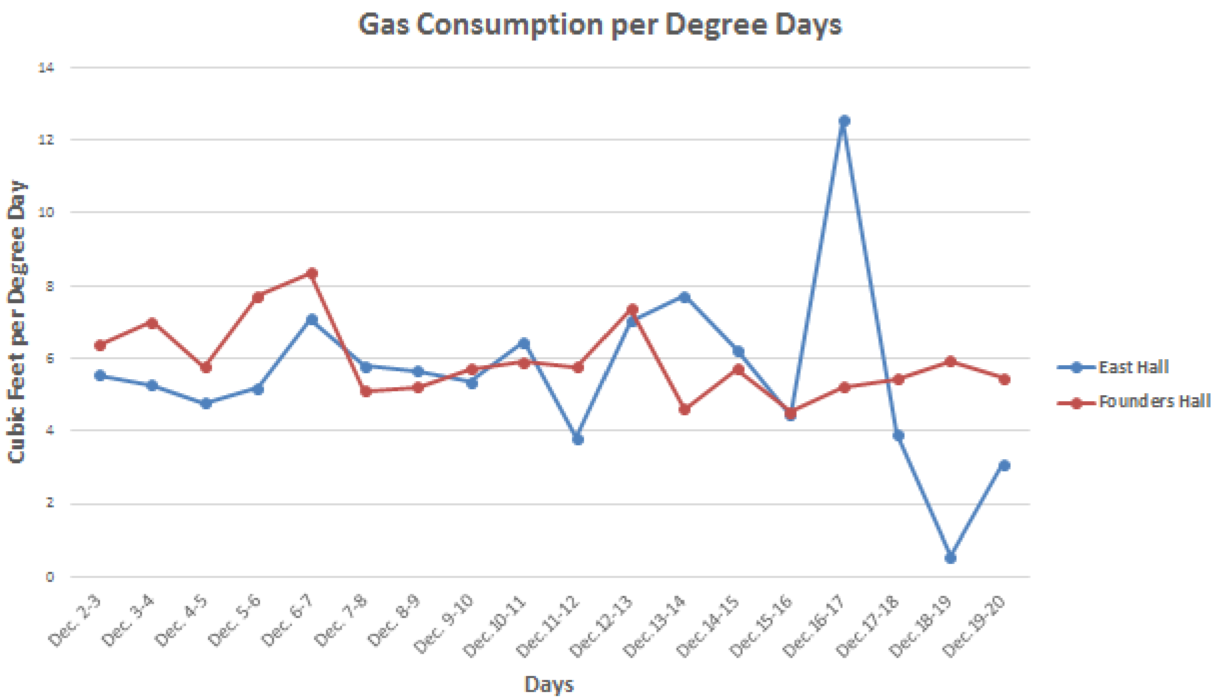


Figure 18: Gas consumption per Degree Day

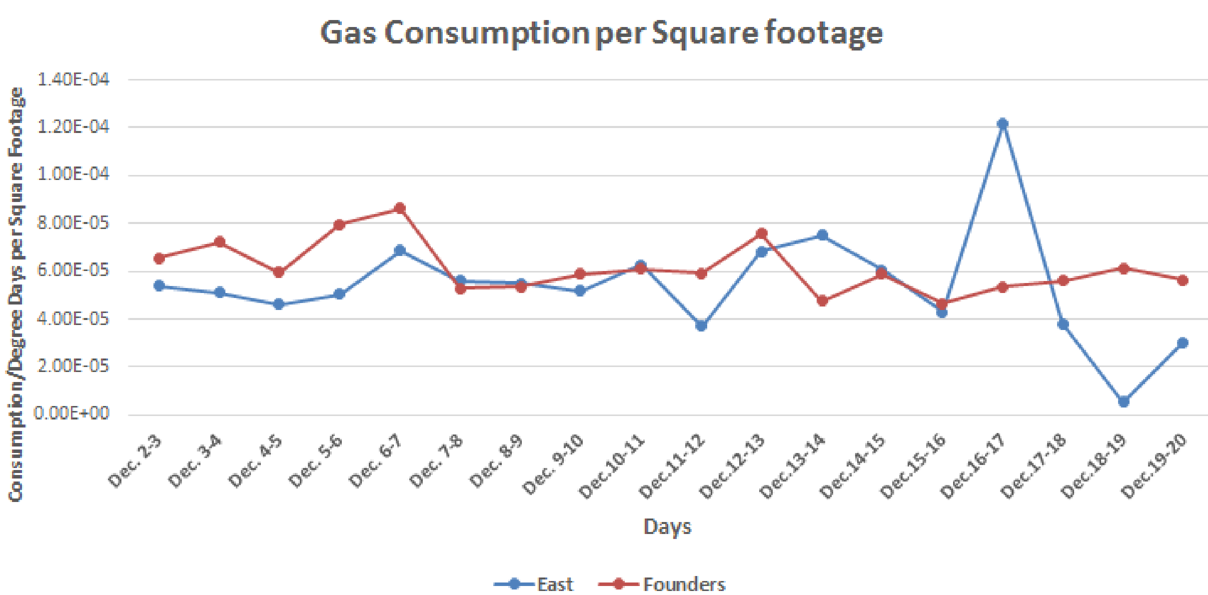


Figure 19: Gas consumption per square footage

Reading the electricity meter is another form of data we collected. The graph below presents the daily consumption of electricity of both buildings and the outside temperature of that particular day. Upon examining Figure 20, there is no direct correlation of temperature affecting the electricity usage. This is interesting because East Hall's HVAC system is controlled using electricity, but it is not a factor to which the electricity consumption fluctuates as the gas to Founders Hall. East Hall overall consumes more electricity than Founders Hall and this does make sense because East Hall is a much laminated building with a full size refrigerator and stove in each suite and a 24-hour garage.

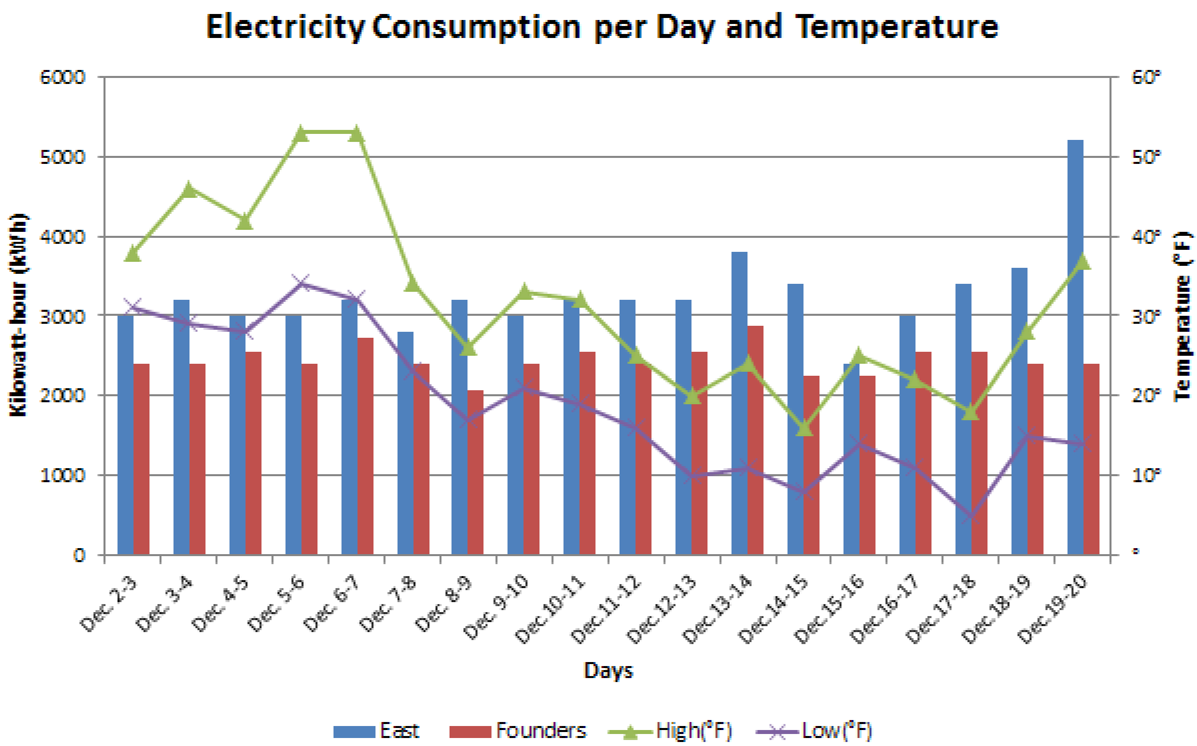


Figure 20: Electricity consumption from December 2-20

To understand the overview building energy consumption (gas and electric) it is important to use the correct unit of energy. In this case we will use kilowatt-hour. To convert the gas consumption from centum cubic feet (ccf = 100 cubic feet) to kilowatt-hour (kWh) the following steps and equations:

Table 7: Conversion of ccf to kWh

ccf to therms	1 ccf = 1.023 therms
therms to BTU	1 therm = 100,000 BTU
BTU to Joules	1 BTU = 1055.05585 joules
Joules to kWh	Kilowatt = joule / (1000 × second)

These numbers are from our metering data collection (Dec. 2 – 20, 2013) during school year.

- East Gas:
    - First reading Dec. 2, 2013—25092 ft^3
    - Second reading Dec. 20, 2013—29081 ft^3
    - Difference (CCF used in 19 days)—3989 ft^3
    - Converted to kilowatt-hour: 116,867 kWh

- Founders Main Gas:
    - First reading Dec. 2, 2013—775420 ft^3
    - Second reading Dec. 20, 2013—779524 ft^3
    - Difference (CCF used in 19 days) —4104 ft^3
    - Converted to kilowatt-hour: 123,043 kWh
- Founders Goats Head Gas:
    - First reading Dec. 2, 2013—38474 ft^3
    - Second reading Dec. 20, 2013—39075 ft^3
    - Difference (CCF used in 19 days) —601 ft^3
    - Converted to kilowatt-hour: 18,019 kWh
- East Electric:
    - First reading Dec. 2, 2013—6258400 kWh
    - Second reading Dec. 20, 2013—6317200 kWh
    - Difference (19 days) —58800 kWh
- Founders Electric:
    - First reading Dec. 2, 2013—5027360 kWh
    - Second reading Dec. 20, 2013— 5071520 kWh
    - Difference (19 days) —44160 kWh

Table 8: Energy Consumption from December 2 to December 20

Utilities (kWh)	East	Founders
Gas	116867	123043
Electric	58800	44160
Total	175667	167203
Per resident[4] per day	40.2	35.3
Per day	9246	8800
Per square foot per day	0.089	0.091

The table above shows some very important information of the overview consumption of buildings. In East Hall each resident consumes about 40.2 kWh per day compared to Founders 35.3 kWh, but yet Founders consumes 2% more energy per square foot per day.

These numbers are from our metering data collection (Dec. 20, 2013 to January 16, 2014) during winter break.

- East Gas:
    - First reading Dec. 20, 2013— 29081 ft^3
    - Second reading Jan. 16, 2014—34665 ft^3

[4] East (Fall 2013) 230 occupants, Founders (Fall 2013) 249 occupants

- Difference (CCF used in 28 days) —5584 ft^3
- Converted to kilowatt-hour: 167,415 kWh

- Founders Main Gas:
  - First reading Dec. 20, 2013—779524 ft^3
  - Second reading Jan. 16, 2014—784096 ft^3
  - Difference (CCF used in 28 days) —4572 ft^3
  - Converted to kilowatt-hour: 130,980 kWh
- Founders Goats Head Gas:
  - First reading Dec. 20, 2013—39075 ft^3
  - Second reading Jan. 16, 2014—39165 ft^3
  - Difference (CCF used in 28 days) —90 ft^3
  - Converted to kilowatt-hour: 2698 kWh
- East Electric:
  - First reading Dec. 20, 2013—6317200 kWh
  - Second reading Jan. 16, 2014—6382800 kWh
  - Difference (28 days) —65600 kWh
- Founders Electric:
  - First reading Dec. 20, 2013—5071520 kWh
  - Second reading Jan. 16, 2014—5109920 kWh
  - Difference (28 days) —38400 kWh

Table 9: Energy consumption from December 20 to January 16

Utilities (kWh)	**East**	**Founders**
Gas	167415	130980
Electric	65600	38400
Total	233015	169380
Per resident* per day	NA	NA
Per day	8322	6049
Per square foot per day	0.081	0.062

Table 10: Consumption per day

(kWh)	**East**	**Founders**
Dec. 2 – 20, 2013 (19 days)	9246	8800
Dec. 20 – Jan 16, 2014 (28 days)	8322	6049
Difference per day	924	2751

The consumption per day table represents how much energy the buildings consumes per day with residents in them (December 2-20) to no residents in them (December 20 to January 16). What is interesting about East Hall is that the difference with to without the residents is only about 10% difference while Founders Hall has a 31% difference. This is surprising because this means it costs more to operate East Hall than it does Founders Hall.

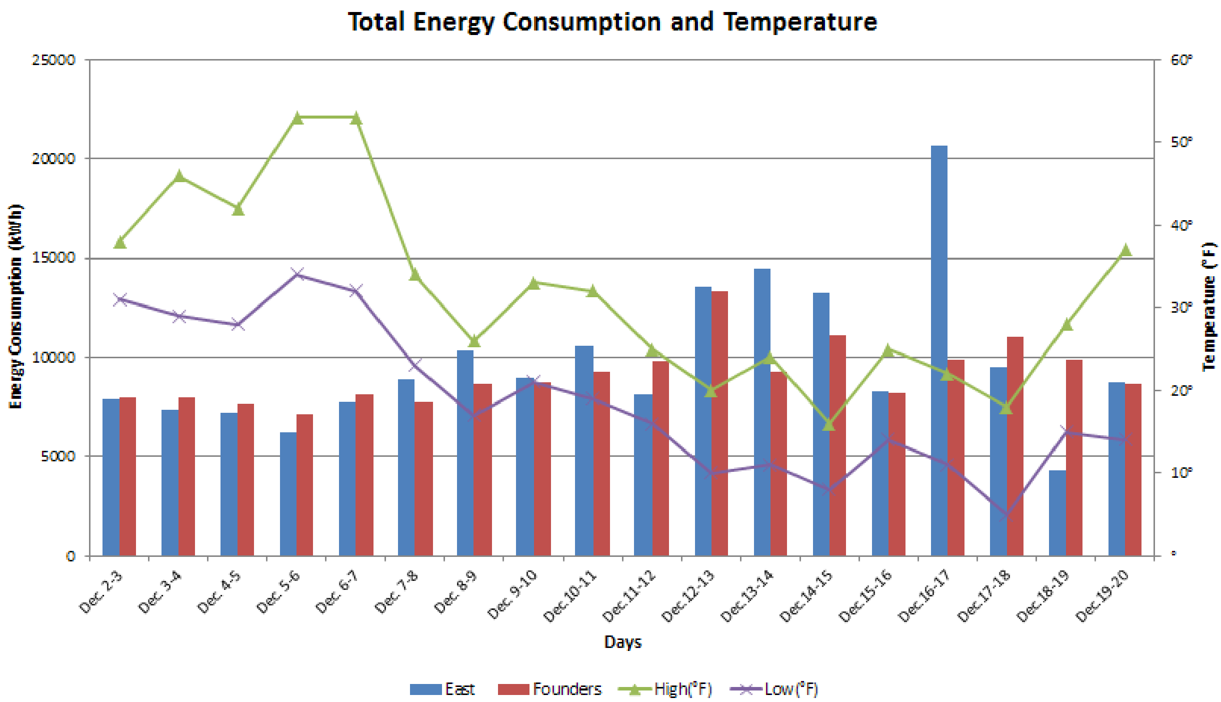


Figure 21: Total Energy consumption and temperature

Figure 22: East Hall Electric Meter

Figure 23: East Hall Gas Meter

Figure 24: Founders Hall electric metering webcam setup

4.4: Energy Bills

WPI's January 2014 bills were used to view the electricity and gas consumption history of East Hall and Founders Hall. In Appendix J, the bills are shown from NSTAR (gas) and National Grid (electricity). Again as a reminder, WPI pays NSTAR and National Grid for the delivery/service of the utility, gas and electricity. These bills provide a 12 month usage history of the buildings, except for the Founders Hall NSTAR bill which is missing May, June, and August. Before looking at the usage history of the bills, it is important to understand the units the utility companies are using. For example, NSTAR charges by the therm even though the gas meters are measuring in centum cubic feet (ccf = 100 cubic feet). Figure 25 presents how NSTAR converts the ccf to therms. NSTAR takes the difference of the billing period and multiplies it by the therm factor which, in this example, is 1.0296. Now this number represents the East Hall actual energy usage.

Gas Used

Rate 27-Commercial Heating
Meter 0051202

Jan 16, 2014 Estimated Read	786369
Dec 16, 2013 Estimated Read -	778772
CCF Used in 31 Days	7597
Times Therm Factor X	1.0295
Therms Billed this Meter	7821

Figure 25: NSTAR conversion ccf to therms

On the National Grid bill, it's the same concept but the only difference is that the electric meter measures in kilowatt-hours and all they have to do is multiply it by Meter Multiplier. The reason the electric meter is multiplied by a meter multiplier is because on the meters the actual amount of energy used is too large to be displayed, so the meter just displays a fraction of the actual use, as shown in Figure 26.

DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading -	Previous Reading =	Difference x	Meter Multiplier =	Total Usage
Energy	31955 *Actual*	31636 *Actual*	319	160	51040 kWh
				Total Energy	**51040 kWh**

Figure 26: National Grid Meter Multiplier

To express the consumption of electricity and gas in a more direct sense, the energy unit kWh and therm is converted into dollars according to WPI's condition. Both electricity and natural gas bills consist of two parts: the actual bill paid for the energy and the bill paid for distributing electricity/natural gas.

For electricity, the following equation:

$$Bill\ charged\ =\ (\$0.1 + \$0.03)\ *\ electricity\ used\ (in\ kWh)$$

Where the factor 0.1 is the charge per kWh electricity used (see Appendix J), and 0.03 is the combined charge for delivery per kWh, including the factors for distribution, transition, transmission, energy efficiency and renewable energy charge. For detailed value for these factors, Appendix J.

For gas, the following steps are taken:

1. The charge for natural gas by Hess Energy is around $4.6 per MBtu [28],

$$\$4.6\ =\ 1 * 10^6\ Btu$$

2. Convert to therms:

$$1\,Therm = 100{,}000\,Btu = 0.1\,MBtu$$

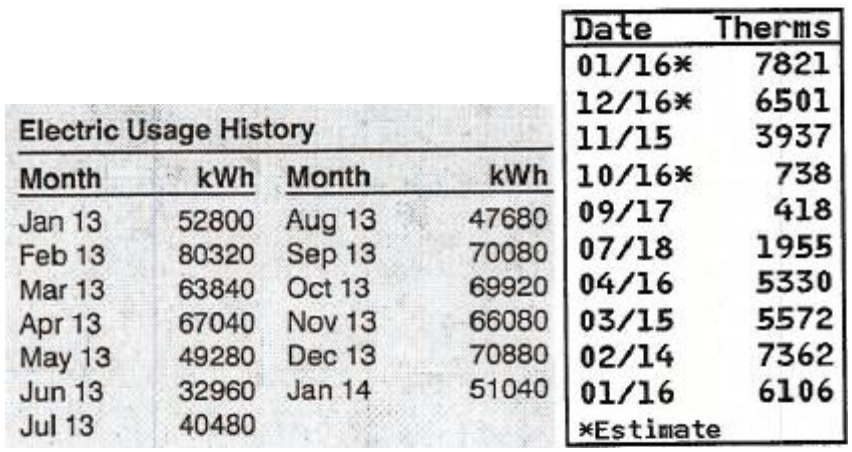
$$\$0.46 = 1\,therm$$

Thus the overall combined charge for natural gas is:

$$Bill\ charged = (\$0.229 + \$0.113 + \$0.46) * natural\ gas\ consumed\ (in\ Therms)$$

The factor 0.229 and 0.113 come from the charge for delivering the natural gas WPI's bill for Founders Hall Year 12-13.

Using this cost information and the consumption history of both buildings, Figure 27 and Figure 28, we are able to combine this information and create a graph representing the cost of each month. In Figure 30, we are not sure why NSTAR does not present the months of May, June, and August.



Electric Usage History

Month	kWh	Month	kWh
Jan 13	52800	Aug 13	47680
Feb 13	80320	Sep 13	70080
Mar 13	63840	Oct 13	69920
Apr 13	67040	Nov 13	66080
May 13	49280	Dec 13	70880
Jun 13	32960	Jan 14	51040
Jul 13	40480		

Date	Therms
01/16*	7821
12/16*	6501
11/15	3937
10/16*	738
09/17	418
07/18	1955
04/16	5330
03/15	5572
02/14	7362
01/16	6106

*Estimate

Figure 27: Founders Hall Electricity and Gas consumption history

Electric Usage History

Month	kWh	Month	kWh
Jan 13	79400	Aug 13	112000
Feb 13	100200	Sep 13	107400
Mar 13	86200	Oct 13	99800
Apr 13	86000	Nov 13	87800
May 13	89200	Dec 13	96200
Jun 13	90800	Jan 14	83800
Jul 13	116600		

Date	Therms
01/15	5959
12/18	6566
11/15	3171
10/16	1346
09/17	781
08/15	306
07/18	411
06/14	795
05/16	1713
04/16	4271
03/15	5038
02/14	6872
01/16	5967

Figure 28: East Hall Electricity and Gas consumption history

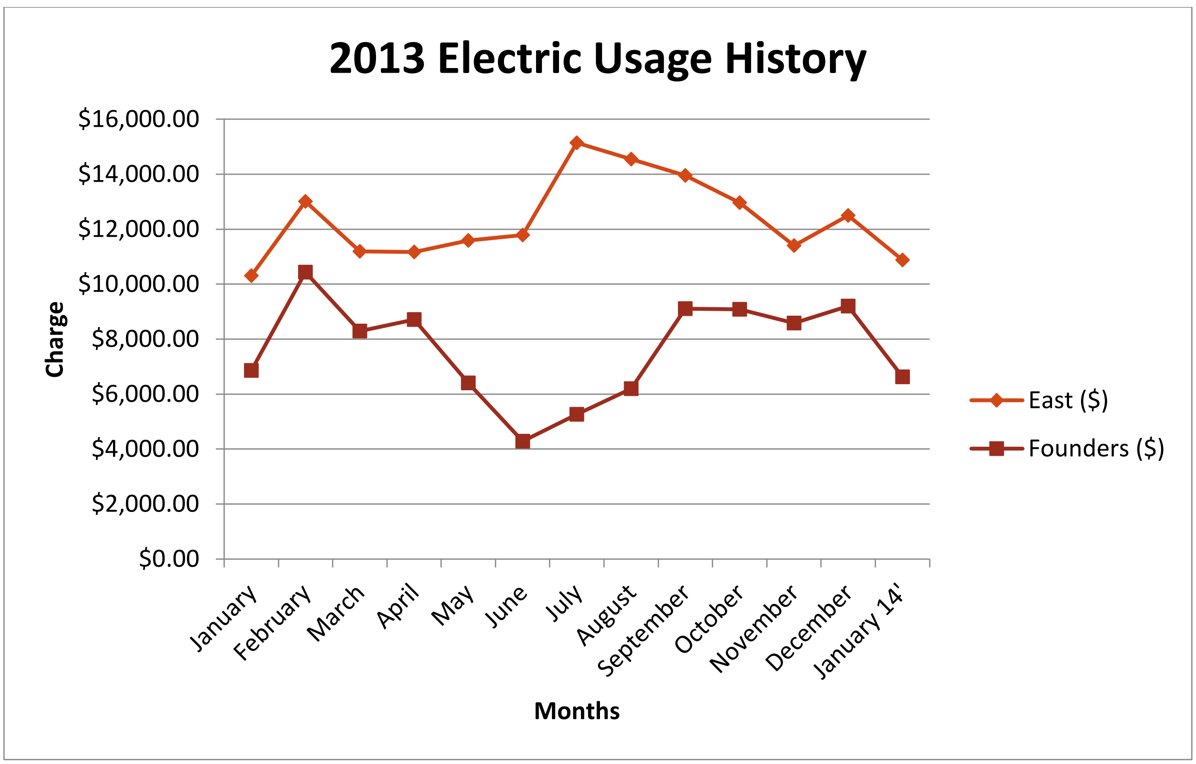


Figure 29: 2013 Electricity usage histories of East Hall and Founders Hall

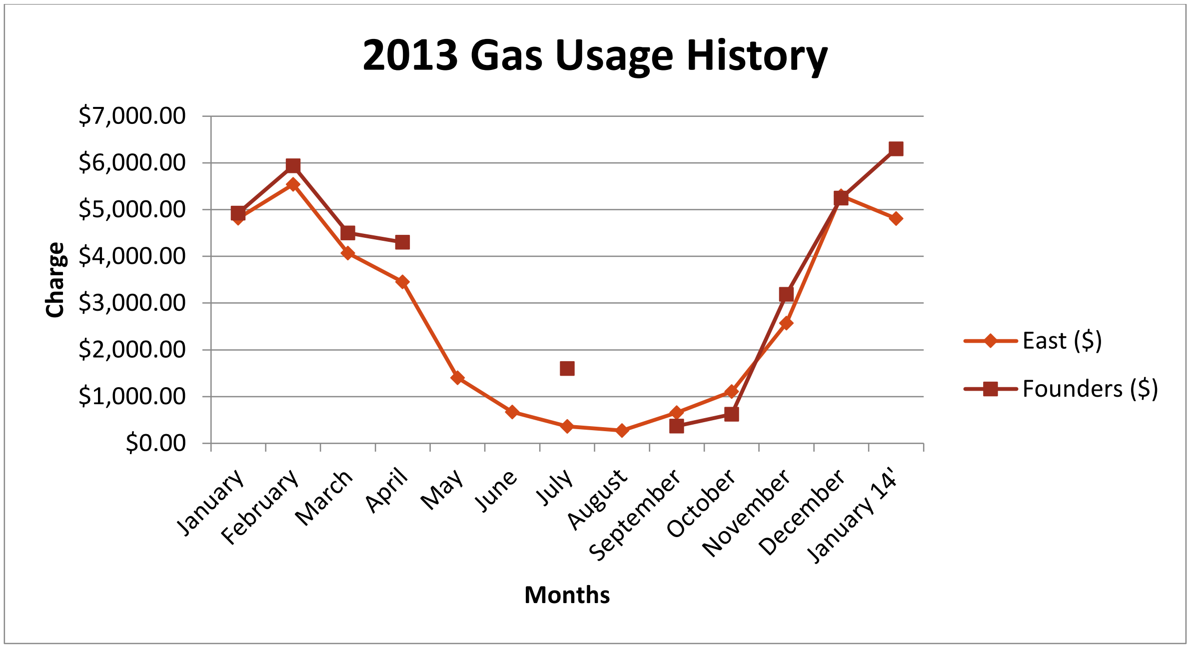


Figure 30: 2013 Gas usage histories of East Hall and Founders Hall

Using the data provided by NSTAR and National Grid, the yearly energy operating cost of East Hall can be estimated at $195,474.75, while the cost for Founders Hall can be estimated at $139,644.85. The difference of $56,829.90 shows Founders Hall consumes about 29% less energy in a year than East Hall. This demonstrates that East Hall, a LEED Gold certified building, is not cost efficient compared to Founders Hall, a non-LEED certified building.

Chapter 5: Recommendations and Conclusions

Finally, from all of the information that was obtained throughout the course of this project we can provide recommendations from our findings. These will be divided into three appropriate parts.

5.1: Immediate Implementation

There are certain things that can be done right away to improve the efficiency of the buildings in question. The first thing is making sure that all of the exits of both East Hall and Founders Hall are sealed, most specifically in the East Hall Trash Room shown in Figure 7. There are also windows in Founders Hall that can be changed because they let in a draft. This was something that the residents of Founders Hall stated in the survey. Something that is not present in neither East Hall nor Founders Hall are light level sensors. This would be something that controlled the lights inside the building according to how much sunlight is already being let in through the windows and doors. East Hall currently has occupancy sensors but Founders Hall does not. Occupancy sensors could be installed in multiple parts of Founders Hall to minimize the time lights are left on.

5.2: Future Implementation

There are certain things that we learned about the buildings that can only serve as recommendations for future buildings. In Founders Hall a major theme was the lighting in the suite. The reason why the lighting levels in Founders Hall were so low in certain areas was not because of the type of bulb or size of bulb, but almost entirely because of where the light is placed. In the future, lights should be placed primarily according to where students' work areas will be. Very similar to this is the use of natural light. Large windows are very important in a building that wants to be efficient because it not only is a source of light, but it can also be a source of warmth, other than a heater. Another important thing to consider when designing a new building is thermal comfort from the resident's point of view. Thermal comfort in this context means better thermostat control and more heating zones. Better thermostat control is a factor because although East Hall has sensors that are directly connected to the air conditioning system, residents deliberately try to trick the thermostat into thinking the room is a different temperature than it actually is to make the thermostat do something else. In Founders Hall the residents wanted better control of the thermostat because the singles got much warmer than the doubles, and at a much faster rate. This caused the residents to turn the thermostat either extremely high or low, back and forth, overworking the heating system, therefore causing it to be an efficient use of energy.

5.3: Behavior Changes

The residents of Founders Hall bring extra lamps with them to light up their workspace. We recommend that the Residential Services Office provide information to new incoming residents of Founders Hall of specific models of lamps and bulbs that are more efficient. It could even be a requirement that all desk lamps use CFLs. This would be effective if the RA's of Founders Hall checked each lamp in the beginning of the year. Sometimes a person that does not usually turn off the lights when they leave a room, will do so if they are asked. Posters and advertisements are very important in trying to get more people to pay attention to something. Heavily trafficked areas like bathroom doors and entrances are great places for advertising sustainability. Quick facts are things that people can read easily and remember easily, yet can make a large impact. Also, the appliances in the kitchen areas are very important as well. We found that the residents will use what is readily available to them and what is most convenient. If the residents are provided with a smaller stove and a smaller oven they will still use it just as much. When installing the appliances the difference will not be seen directly by the residents using them, but rather on the energy bills.

5.4: LEED

When it comes to LEED Certification, there was no significant difference in energy consumption that provided us with a definitive reason why a LEED certified building is more energy efficient than one that is not LEED certified. When East Hall received its LEED Gold Certification, one of the things that East Hall was not awarded points for was thermal comfort. As we've mentioned before, this was something with which the residents were not satisfied. Overall LEED Certification does not mean that the building in question will perform better than its counterpart on all fronts because we've shown that East Hall does consume more energy than Founders Hall, a much older building.

5.5: Future Projects

For future projects, we have multiple recommendations:

- Evaluate other buildings on campus, especially academic buildings. There are many buildings that either have already been retrocommissioned, or are in the process of retrocommissioning.
- Develop new recommendations on best practices for new building construction. Areas that can be closely researched and addressed are how to light the building and how to heat the building, of course in the most sustainable and energy efficient manner possible.
- Enhance real-time data collection. Perhaps there could be a project devoted to developing a system that allows WPI Facilities to monitor each building individually.

Each of these projects would contribute to the continuing efforts to enhance the sustainability of the WPI campus.

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Appendices

Appendix A: East Hall LEED Scorecard

LEED for New Construction v2.2

East Hall, WPI
Project # 10072670
Certification Level: Gold
June 25, 2009

44 Points Achieved — Possible Points: 69

Certified 26 to 32 points Silver 33 to 38 points Gold 39 to 51 points Platinum 52 or more points

12 Sustainable Sites — Possible Points: 14

Y	Prereq 1	**Construction Activity Pollution Prevention**	
1	Credit 1	**Site Selection**	1
1	Credit 2	**Development Density & Community Connectivity**	1
	Credit 3	**Brownfield Redevelopment**	1
1	Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
1	Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
1	Credit 4.3	**Alternative Transportation**, Low-Emitting & Fuel-Efficient Vehicles	1
	Credit 4.4	**Alternative Transportation**, Parking Capacity	1
1	Credit 5.1	**Site Development**, Protect or Restore Habitat	1
1	Credit 5.2	**Site Development**, Maximize Open Space	1
1	Credit 6.1	**Stormwater Design**, Quantity Control	1
1	Credit 6.2	**Stormwater Design**, Quality Control	1
1	Credit 7.1	**Heat Island Effect**, Non-Roof	1
1	Credit 7.2	**Heat Island Effect**, Roof	1
1	Credit 8	**Light Pollution Reduction**	1

4 Water Efficiency — Possible Points: 5

1	Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
1	Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
	Credit 2	**Innovative Wastewater Technologies**	1
1	Credit 3.1	**Water Use Reduction**, 20% Reduction	1
1	Credit 3.2	**Water Use Reduction**, 30% Reduction	1

7 Energy & Atmosphere — Possible Points: 17

Y	Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	
Y	Prereq 2	**Minimum Energy Performance**	
Y	Prereq 3	**Fundamental Refrigerant Management**	
1	Credit 1.1	**Optimize Energy Performance**, 10.5% New / 3.5% Existing	1
1	Credit 1.2	**Optimize Energy Performance**, 14% New / 7% Existing	1
1	Credit 1.3	**Optimize Energy Performance**, 17.5% New / 10.5% Existing	1
1	Credit 1.4	**Optimize Energy Performance**, 21% New / 14% Existing	1
1	Credit 1.5	**Optimize Energy Performance**, 24.5% New / 17.5% Existing	1
	Credit 1.6	**Optimize Energy Performance**, 28% New / 21% Existing	1
	Credit 1.7	**Optimize Energy Performance**, 31.5% New / 24.5% Existing	1
	Credit 1.8	**Optimize Energy Performance**, 35% New / 28% Existing	1
	Credit 1.9	**Optimize Energy Performance**, 38.5% New / 31.5% Existing	1
	Credit 1.10	**Optimize Energy Performance**, 42% New / 35% Existing	1
	Credit 2.1	**Renewable Energy**, 2.5%	1
	Credit 2.2	**Renewable Energy**, 7.5%	1
	Credit 2.3	**Renewable Energy**, 12.5%	1
1	Credit 3	**Enhanced Commissioning**	1
1	Credit 4	**Enhanced Refrigerant Management**	1
	Credit 5	**Measurement & Verification**	1
	Credit 6	**Green Power**	1

7 Materials & Resources — Possible Points: 13

Y	Prereq 1	**Storage & Collection of Recyclables**	
	Credit 1.1	**Building Reuse**, Maintain 75% of Existing Walls, Floors, & Roof	1
	Credit 1.2	**Building Reuse**, Maintain 95% of Existing Walls, Floors, & Roof	1
	Credit 1.3	**Building Reuse**, Maintain 50% of Interior Non-Structural Elements	1
1	Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
1	Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
	Credit 3.1	**Materials Reuse**, 5%	1
	Credit 3.2	**Materials Reuse**, 10%	1
1	Credit 4.1	**Recycled Content**, 10%	1
1	Credit 4.2	**Recycled Content**, 20%	1
1	Credit 5.1	**Regional Materials**, 10%	1
1	Credit 5.2	**Regional Materials**, 20%	1
	Credit 6	**Rapidly Renewable Materials**	1
1	Credit 7	**Certified Wood**	1

10 Indoor Environmental Quality — Possible Points: 15

Y	Prereq 1	**Minimum IAQ Performance**	
Y	Prereq 2	**Environmental Tobacco Smoke** (ETS) Control	
	Credit 1	**Outdoor Air Delivery Monitoring**	1
	Credit 2	**Increase Ventilation**	1
1	Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
1	Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
1	Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
1	Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1
1	Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1
1	Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber Products	1
	Credit 5	**Indoor Chemical & Pollutant Source Control**	1
1	Credit 6.1	**Controllability of Systems**, Lighting	1
1	Credit 6.2	**Controllability of Systems**, Thermal Comfort	1
	Credit 7.1	**Thermal Comfort**, Design	1
	Credit 7.2	**Thermal Comfort**, Verification	1
1	Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
1	Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1

4 Innovation & Design Process — Possible Points: 5

1	Credit 1.1	**Innovation in Design**: Green Building Education	1
1	Credit 1.2	**Innovation in Design**: Green Housekeeping	1
	Credit 1.3	**Innovation in Design**:	1
1	Credit 1.4	**Innovation in Design**: SSc5.2	1
1	Credit 2	LEED® Accredited Professional	1

Appendix B: WPI Buildings Supplied by Power House

B.1: Electricity

Buildings Receiving Electricity from: Main Meter at 183 West Street (Power House)

1. Alden Hall (Auditorium, Classrooms)
2. Alumni Gym (Gym, Offices, Pool)
3. Alumni Gym Extension (Locker Rooms, Offices)
4. Atwater Kent (Classrooms, Labs)
5. Bartlett Center (Admissions, Financial Aid)
6. Boynton Hall (Offices, Administration)
7. Campus Center (Offices, Meeting Rooms, Dining)
8. Daniels Hall (Residence Halls, Offices)
9. Fuller Labs (Classrooms, Auditorium)
10. Goddard Hall (Classrooms, Labs, Offices)
11. Gordon Library (Library, Meeting Rooms)
12. Harrington Auditorium (Gymnasium, Classrooms)
13. Higgins House (Offices, Food Service, Meeting Rooms)
14. Higgins House Garage (Storage, Offices)
15. Higgins Labs (Classrooms, Labs)
16. Kaven Hall (Classrooms, Labs)
17. Morgan Daniels Wedge (Meeting Rooms)
18. Morgan Hall (Residence Hall, Offices, Food Service)
19. Olin Hall (Classrooms)
20. Powerhouse (Boiler Room)
21. Project Center (Offices, Classrooms)
22. Salisbury Labs (Classrooms, Labs)
23. Sanford Riley Hall (Residence Hall, Administration)
24. Skull Tomb (Meeting Place)
25. Stratton Hall (Classrooms, Offices, Physical Plant Workshops, Storerooms)
26. Washburn (Classrooms, Labs)
27. Field House (Storage)
28. Football Field Garage (Storage)
29. Press Box / Bleachers (Press Box)

TOTAL: 29 Buildings / Properties

B.2: Steam

Buildings Receiving Steam from: Central Heating Plant at 183 West Street (Power House)

1. Alden Hall (Auditorium, Classrooms)
2. Alumni Gym (Gym, Offices, Pool)
3. Alumni Gym Extension (Locker Rooms, Offices)
4. Atwater Kent (Classrooms, Labs)
5. Bartlett Center (Admissions, Financial Aid)
6. Boynton Hall (Offices, Administration)
7. Campus Center (Offices, Meeting Rooms, Dining)
8. Daniels Hall (Residence Halls, Offices)
9. Fuller Labs (Classrooms, Auditorium)
10. Goddard Hall (Classrooms, Labs, Offices)
11. Gordon Library (Library, Meeting Rooms)
12. Harrington Auditorium (Gymnasium, Classrooms)
13. Higgins Labs (Classrooms, Labs)
14. Kaven Hall (Classrooms, Labs)
15. Morgan Daniels Wedge (Meeting Rooms)
16. Morgan Hall (Residence Hall, Offices, Food Service)
17. Olin Hall (Classrooms)
18. Powerhouse (Boiler Room)
19. Project Center (Offices, Classrooms)
20. Salisbury Labs (Classrooms, Labs)
21. Sanford Riley Hall (Residence Hall, Administration)
22. Stratton Hall (Classrooms, Offices, Physical Plant Workshops, Storerooms)
23. Washburn (Classrooms, Labs)
24. Recreation Center

TOTAL: 24 Buildings / Properties

B.3: Map of WPI Buildings Receiving Energy from the Power House

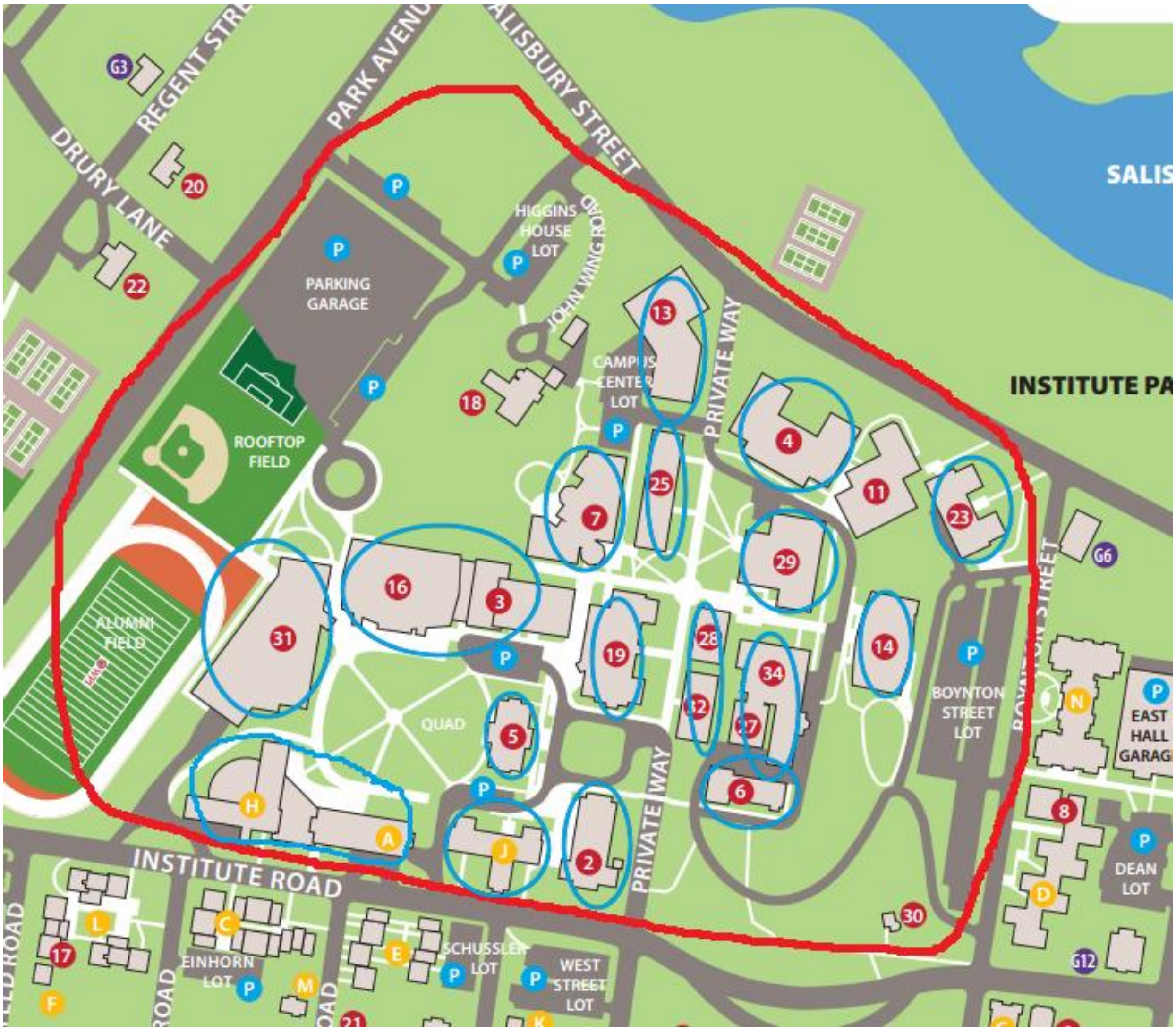


Figure 31: Buildings receiving energy from the Power House

Appendix C: Meter Tracking Sheets

C.1: Founders Main Gas

Founders Main Gas					
			Temperature		
Date	Meter Number (f^3)	Time	High(°F)	Low(°F)	Δ Meter (f^3)
Dec. 2,2013	775420	7:59AM	38	31	
Dec. 3,2013	775611	7:58AM	46	29	191
Dec. 4,2013	775800	8:01AM	42	28	189
Dec. 5,2013	775973	7:57AM	53	34	173
Dec. 6,2013	776135	7:49AM	53	32	162
Dec. 7,2013	776319	10:32AM	34	23	184
Dec. 8,2013	776503	8:53AM	26	17	184
Dec. 9,2013	776727	8:29AM	33	21	224
Dec. 10,2013	776944	7:50AM	32	19	217
Dec. 11,2013	777174	7:53AM	25	16	230
Dec. 12,2013	777427	7:55AM	20	10	253
Dec. 13,2013	777795	7:56AM	24	11	368
Dec. 14,2013	778012	12:20PM	16	8	217
Dec. 15,2013	778315	1:48PM	25	14	303
Dec. 16,2013	778518	8:59AM	22	11	203
Dec. 17,2013	778768	8:00AM	18	5	250
Dec. 18,2013	779056	8:03AM	28	15	288
Dec. 19,2013	779311	8:43AM	37	14	255
Dec. 20,2013	779524	6:59AM	46	38	213
Jan. 16, 2014	784096	10:46AM	37	32	4572

C.2: The Goats Head Restaurant Gas

Founders Goat's Head Gas					
			Temperature		
Date	Meter Number (f^3)	Time	High(°F)	Low(°F)	Δ Meter (f^3)
Dec. 2,2013	38474	7:52AM	38	31	
Dec. 3,2013	38519	7:58AM	46	29	45
Dec. 4,2013	38543	8:01AM	42	28	24
Dec. 5,2013	38574	7:57AM	53	34	31
Dec. 6,2013	38604	7:49AM	53	32	30
Dec. 7,2013	38634	10:32AM	34	23	30
Dec. 8,2013	38666	8:53AM	26	17	32
Dec. 9,2013	38708	8:30AM	33	21	42
Dec. 10,2013	38732	7:50AM	32	19	24
Dec. 11,2013	38766	7:53AM	25	16	34
Dec. 12,2013	38797	7:55AM	20	10	31
Dec. 13,2013	38832	7:56AM	24	11	35
Dec. 14,2013	38868	12:20PM	16	8	36
Dec. 15,2013	38901	1:48PM	25	14	33
Dec. 16,2013	38934	8:59AM	22	11	33
Dec. 17,2013	38966	8:00AM	18	5	32
Dec. 18,2013	39001	8:03AM	28	15	35
Dec. 19,2013	39034	8:43AM	37	14	33
Dec. 20,2013	39075	6:59AM	46	38	41
Jan. 16, 2014	39165	10:46AM	37	32	90

C.3: Founders Electric

Founders Hall Electric								
		Meter Number	Max kVA/kW Delivered	Total kWh Delivered	Max kW/kVA Delivered	Register Constant	CMT ID (Program ID)	**Δ Meter (kWh)**
Date	Time	*005	*003	*004	*010	*030	*050	
Dec. 2,2013	7:26AM	800149	001.08	31421	001.05	001.800	00045	
Dec. 3,2013	7:37AM	800149	001.08	31436	001.05	001.800	00045	15
Dec. 4,2013	7:26AM	800149	001.08	31451	001.05	001.800	00045	15
Dec. 5,2013	7:22AM	800149	001.08	31467	001.05	001.800	00045	16
Dec. 6,2013	7:23AM	800149	001.08	31482	001.05	001.800	00045	15
Dec. 7,2013	10:40AM	800149	001.08	31499	001.05	001.800	00045	17
Dec. 8,2013	10:25AM	800149	001.08	31514	001.05	001.800	00045	15
Dec. 9,2013	7:42AM	800149	001.08	31527	001.05	001.800	00045	13
Dec. 10,2013	7:25AM	800149	001.08	31542	001.05	001.800	00045	15
Dec. 11,2013	7:23AM	800149	001.08	31558	001.05	001.800	00045	16
Dec. 12,2013	7:23AM	800149	001.08	31573	001.05	001.800	00045	15
Dec. 13,2013	7:21AM	800149	001.08	31589	001.05	001.800	00045	16
Dec. 14,2013	12:30PM	800149	001.08	31607	001.05	001.800	00045	18
Dec. 15,2013	9:31AM	800149	001.08	31621	001.05	001.800	00045	14
Dec. 16,2013	7:26AM	800149	001.08	31635	001.05	001.800	00045	14
Dec. 17,2013	8:12AM	800149	001.00	31651	000.97	001.800	00045	16
Dec. 18,2013	7:32AM	800149	001.00	31667	000.97	001.800	00045	16
Dec. 19,2013	7:17AM	800149	001.00	31682	000.97	001.800	00045	15
Dec. 20,2013	7:58AM	800149	001.01	31697	000.99	001.800	00045	15
Jan. 16, 2013	7:24AM	800149	001.08	31937	001.06	001.800	00045	

C.4: East Gas

East Hall Gas					
			Temperature		
Date	Meter Number (f^3)	Time	High(°F)	Low(°F)	Δ Meter (f^3)
Dec. 2,2013	25092	7:59AM	38	31	
Dec. 3,2013	25258	8:04AM	46	29	166
Dec. 4,2013	25400	8:06AM	42	28	142
Dec. 5,2013	25543	8:02AM	53	34	143
Dec. 6,2013	25652	8:52AM	53	32	109
Dec. 7,2013	25808	10:28AM	34	23	156
Dec. 8,2013	26016	8:49AM	26	17	208
Dec. 9,2013	26259	8:22AM	33	21	243
Dec. 10,2013	26462	8:08AM	32	19	203
Dec. 11,2013	26714	8:00AM	25	16	252
Dec. 12,2013	26882	8:02AM	20	10	168
Dec. 13,2013	27234	7:50AM	24	11	352
Dec. 14,2013	27597	12:13PM	16	8	363
Dec. 15,2013	27927	1:40PM	25	14	330
Dec. 16,2013	28127	9:17AM	22	11	200
Dec. 17,2013	28729	7:58AM	18	5	602
Dec. 18,2013	28936	9:00AM	28	15	207
Dec. 19,2013	28960	11:20AM	37	14	24
Dec. 20,2013	29081	7:03AM	46	38	121
Jan. 16, 2014	34665	10:41AM	37	32	5584

C.5: East Electric

East Hall Electric

Date	Time	Meter Number	Date	Time	Total kWh Delivered	On- Peak kWh Delivered	On- Peak kW/kVA Delivered	On-Peak kVA Delivered	Off-Peak kWh Delivered	Off-Peak kW/kVA Delivered	Off-Peak kVA Delivered	Register Constant	CMT ID (Program ID)	**Δ Meter (kWh)**	**Δ On-Peak Delivered (kWh)**	**Δ Off-Peak Delivered (kWh)**
		*005	*1	*2	*4	*5	*6	*7	*13	*14	*15	*30	*50			
Dec. 2,2013	7:58AM	31049	02.12.13	07:58:19	31292	12522	0.8	0.81	18769	0.8	0.82	1	12			
Dec. 3,2013	8:03AM	31049	03.12.13	08:03:49	31307	12531	0.8	0.81	18776	0.8	0.82	1	12	15	9	7
Dec. 4,2013	8:05AM	31049	04.12.13	08.05.00	31323	12539	0.8	0.81	18783	0.8	0.82	1	12	16	8	7
Dec. 5,2013	8:01AM	31049	05.12.13	08::01:49	31338	12548	0.8	0.81	18789	0.8	0.82	1	12	15	9	6
Dec. 6,2013	8:51AM	31049	06.12.13	08:51:54	31353	12557	0.8	0.81	18796	0.8	0.82	1	12	15	9	7
Dec. 7,2013	10:27AM	31049	07.12.13	10:27:45	31369	12565	0.8	0.81	18804	0.8	0.82	1	12	16	8	8
Dec. 8,2013	8:48AM	31049	08.12.13	08:48:26	31383	12565	0.8	0.81	18818	0.8	0.82	1	12	14	0	14
Dec. 9,2013	8:24AM	31049	09.12.13	08:24:00	31399	12565	0.8	0.81	18833	0.8	0.82	1	12	16	0	15
Dec. 10,2013	8:07AM	31049	10.12.13	08:07:00	31414	12573	0.8	0.81	18840	0.8	0.82	1	12	15	8	7
Dec. 11,2013	8:30AM	31049	11.12.13	08:30:20	31430	12585	0.8	0.81	18848	0.8	0.82	1	12	16	12	8
Dec. 12,2013	8:01AM	31049	12.12.13	08:01:00	31446	12590	0.8	0.81	18855	0.8	0.82	1	12	16	5	7
Dec. 13,2013	7:49AM	31049	13.12.13	07:49:00	31462	12600	0.81	0.82	18862	0.8	0.82	1	12	16	10	7
Dec. 14,2013	12:14PM	31049	14.12.13	12:14:00	31481	12601	0.81	0.82	18872	0.8	0.82	1	12	19	1	10
Dec. 15,2013	1:39PM	31049	15.12.13	13:39:00	31498	12609	0.81	0.82	18889	0.8	0.82	1	12	17	8	17
Dec. 16,2013	9:16AM	31049	16.12.13	09:16:00	31510	12609	0.62	0.63	18901	0.6	0.6	1	12	12	0	2
Dec. 17,2013	7:57AM	31049	17.12.13	07:57:00	31525	12617	0.77	0.78	18908	0.76	0.77	1	12	15	8	7
Dec. 18,2013	8:59AM	31049	18.12.13	08:59:00	31542	12627	0.8	0.82	18915	0.78	0.79	1	12	17	10	7
Dec. 19,2013	11:19AM	31049	19.12.13	11:19:16	31560	12637	0.8	0.82	18922	0.78	0.79	1	12	18	10	7
Dec. 20,2013	7:58AM	31049	20.12.13	07:58:00	31586	12647	0.8	0.82	18937	0.78	0.79	1	12	26	10	15
Jan. 16, 2013	10:42AM	31049	16.01.14	10:42:41	31914	12764	0.8	0.82	19150	0.78	0.79	1	12			

Appendix D: East Hall First Floor Lighting Inventory

Location	Light Type	Quantity	Power Rating (W)	Total Power (W)	LUX Reading
Lobby/Foyer	Compact Fluorescent Light	16	42	672	170-340 (470-600 Day time by the windows)
	Fluorescent Lamp (2ft)	16	17	272	170-340
Tech Suite 107	Fluorescent Lamp (2ft)	8	17	136	143-185(shades down lights on) Shades Up lights off 124 - 560 (Daytime)
Elevator South Hall	Compact Fluorescent Light	5	26	130	64-227
South Hall	Compact Fluorescent Light	8	42	336	56-148
South Hall by Game Room	Fluorescent Lamp (2ft)	8	17	136	80-230
Game room	Fluorescent Lamp (2ft)	24	17	408	102-200
Tech Suite 113A	Fluorescent Lamp (2ft)	8	17	136	100-192

East Hall First Floor Lighting Inventory (continued)

Location	Light Type	Quantity	Power Rating (W)	Total Power (W)	LUX Reading
Tech Suite 118	Fluorescent Lamp (2ft)	12	17	204	100-192
Gym	Fluorescent Lamp (2ft)	20	17	340	125-440
Music room 120	Fluorescent Lamp (2ft)	12	17	204	163-312
Music room 121	Fluorescent Lamp (2ft)	6	17	102	60-180 (This has Occupancy sensor)
North Hall	Compact Fluorescent Light	6	42	252	49-262
Elevator North Hall	Compact Fluorescent Light	2	42	84	60-127
Mechanical Room Hallway	Fluorescent Lamp (2ft)	14	17	238	73-343
Stairway 4 Hall (Northeast)	Fluorescent Lamp (4ft)	24	54	1296	51-370
East 5th floor Hallway	Fluorescent Lamp (4ft)	16	54	864	89-230
	Fluorescent Lamp (2ft)	29	24	696	45-200
	Compact Fluorescent Light	3	42	126	75-230
East 5th floor Tech Suite	Fluorescent Lamp (2ft)	8	17	136	120-220
Stair way 2 (Southwest)	Fluorescent Lamp (4ft)	20	54	1080	170-370
Main Entrance (between door adjacent to Lobby)	Compact Fluorescent Light	2	42	84	125-360

East Hall First Floor Lighting Inventory (continued)

Location	Light Type	Quantity	Power Rating (W)	Total Power (W)	LUX Reading
Men's Restroom	Fluorescent Lamp (4ft)	7	54	378	130-560
	Compact Fluorescent Light	3	42	126	130-560
Tech Suite 106	Fluorescent Lamp (2ft)	4	17	68	100-186
Electric Room Main	Fluorescent Lamp (4ft)	4	54	216	110-160
Emergency Electric Room	Fluorescent Lamp (4ft)	2	54	108	115-162
Chill water room	Fluorescent Lamp (4ft)	8	54	432	60-250
Main trash room (Motion sensor)	Fluorescent Lamp (4ft)	6	54	324	66-234
Loading Dock (Motion senor)	Fluorescent Lamp (4ft)	6	54	324	
Elevator Mech. Room (North)	Fluorescent Lamp (4ft)	2	54	108	150-223
HVAC service Room	Fluorescent Lamp (4ft)	2	54	108	
Telecom room	Fluorescent Lamp (4ft)	6	54	324	78-140
Custodian Closet	Fluorescent Lamp (4ft)	2	54	108	63-209
Laundry room (Electrical room)	Fluorescent Lamp (4ft)	2	54	108	130-240
Laundry room	Fluorescent Lamp (2ft)	16	17	272	118-440

Appendix E: Founders Hall Basement Lighting Inventory

Location	Light Type	Quantity	LUX Reading
051 Mechanical Room	T8 Fluorescent (4ft, 2 bulb)	7	130-430
Freight elevator machine room	T8 Fluorescent (4ft, 2 bulb)	2	250-408
Basement hallway	T8 Fluorescent (4ft, 2 bulb)		56-230
025 Custodian	T8 Fluorescent (4ft, 2 bulb)	1	
Main elevator machine room	T8 Fluorescent (4ft, 2 bulb)	1	130-240
Police station hallway	T8 Fluorescent (4ft, 2 bulb)	9	3-360
Basement network room	T8 Fluorescent (4ft, 2 bulb)	4	230-400
Boiler room	T8 Fluorescent (4ft, 2 bulb)	17	115-220
Electric room	T8 Fluorescent (4ft, 2 bulb)	8	150-600
Generator room	T8 Fluorescent (4ft, 2 bulb)	2	
Generator entrance room	T8 Fluorescent (4ft, 2 bulb)	1	
Generator room closet	T8 Fluorescent (4ft, 2 bulb)	2	
Campus police fitness room	T8 Fluorescent (4ft, 2 bulb)	2	
Dispatch room	U-tube fluorescent		118-290
Officer work room	T8 Fluorescent (4ft, 2 bulb)	5	270-660 lux

Appendix F: East Hall Lighting Fixtures

- Fluorescent Lamps : F17T8/SP41/ECO—17W

Technical Specs

Item	Linear Fluorescent Lamp	Min. Starting Temp.	-441.67 Degrees F
Lamp Shape	T8	Initial Lumens	1325
Base Type	Medium Bi-Pin (G13)	Mean Lumens	1260
Length	24"	Shatter Resistance	No
Diameter	1"	Primary Application	General Purpose
Watts	17	Lamp Designation	F17T8/SP*/ECO
Average Life	36000 hr.	ANSI Code	1001-1
Lamp Tone	Cool	Standards	Meets 2012 Lighting Legislation Energy
Color Temp.	4100K	Case Quantity	24
CRI	78	Green Environmental Attribute	Product Contributes to Reducing Energy Consumption
Start Type	Instant		

http://www.grainger.com/product/GE-LIGHTING-Fluorescent-Linear-Lamp-6XT99

- Compact Fluorescent mini-spiral—26W
  - Light output 1700 lumens
  - Energy Used 26 watts
  - Life 10,000 hours
  - Color Temp 4100K
- Induction Lamp QL 85/830—85W

Brand /	Philips
Lamp's Power	85 W
Part No.	QL 85/830
Supply Current	0.345 A
Operation Frequency	2.65 MHz
Bulb Type	P-110
Overall Length	180.5 mm
Weight	200 grams
Atmosphere	Ar-Kr-Ne | Hg-amalgam
Luminous Flux.	6000 lm @ 100 Hours 4200 lm @ 60000 Hours
Luminous Effecacy	71 lm/W @ 100 Hours 49 lm/W @ 60000 Hours
Color Temp. & CRI	3000K CRI: 80+
Burning Position	Universal
Rated Life	100,000 Hours (To 50% Depreciation)
Warm Up / Re-Strike Time	30 Seconds / Instantanous
Warranty	3 to 5 Years

http://www.bulbspro.com/philips-ql85w-830-induction-lamp-3000k-warm-white.html

- GE compact Fluorescent lamp non-integrated—26W

Technical Specs

Item	Plug-In CFL	Mean Lumens	1460
Overall Lamp Shape	T	Color Temp.	4100K
Dimmable / Non-Dimmable	Non-Dimmable	Average Life	10,000 hr.
Lamp Type	Double Tube	CRI	82
Incandescent Equivalent (Watts)	100	Min. Starting Temp.	16 Degrees F
Watts	26	Lamp Designation	F26DBX/ECO
Base Type	2-Pin (G24D-3)	Start Type	Preheat
Lamp Shape	T4	Footnotes	1,2
Lamp Tone	Cool	Standards	Meets 2012 Lighting Legislation Energy
Max. Overall Length	6-5/8"	Primary Application	General Purpose
Shatter Resistance	No	Green Environmental Attribute	Product Contributes to Reducing Energy Consumption
Initial Lumens	1710		

http://www.grainger.com/product/GE-LIGHTING-Plug-In-CFL-1PGY3

- Incandescent Light bulb—40W
- GE compact Fluorescent lamp (F42TBX/835/A/ECO)—42W

Technical Specs

Item	Plug-In CFL	Mean Lumens	2690
Overall Lamp Shape	T	Color Temp.	3500K
Dimmable / Non-Dimmable	Dimmable	Average Life	17,000 hr.
Lamp Type	Triple Tube	CRI	82
Incandescent Equivalent (Watts)	150	Min. Starting Temp.	0 Degrees F
Watts	42	Lamp Designation	F42TBX/A/ECO
Base Type	4-Pin (GX24Q-4)	Start Type	Rapid
Lamp Shape	T4	Footnotes	1,2,6,12
Lamp Tone	Neutral	Standards	Meets 2012 Lighting Legislation Energy
Max. Overall Length	6-3/8"	Primary Application	General Purpose
Shatter Resistance	No	Green Environmental Attribute	Product Contributes to Reducing Energy Consumption
Initial Lumens	3200		

http://www.grainger.com/product/GE-LIGHTING-Plug-In-CFL-1PHA8

- GE compact Fluorescent lamp (F42TBX/841/A/ECO)—42W

Technical Specs

Item	Plug-In CFL	Mean Lumens	2690
Overall Lamp Shape	T	Color Temp.	4100K
Dimmable / Non-Dimmable	Dimmable	Average Life	17,000 hr.
Lamp Type	Triple Tube	CRI	82
Incandescent Equivalent (Watts)	150	Min. Starting Temp.	0 Degrees F
Watts	42	Lamp Designation	F42TBX/A/ECO
Base Type	4-Pin (GX24Q-4)	Start Type	Rapid
Lamp Shape	T4	Footnotes	1,2,6
Lamp Tone	Cool	Standards	Meets 2012 Lighting Legislation Energy
Max. Overall Length	6-3/8"	Primary Application	General Purpose
Shatter Resistance	No	Green Environmental Attribute	Product Contributes to Reducing Energy Consumption
Initial Lumens	3200		

http://www.grainger.com/product/GE-LIGHTING-Plug-In-CFL-1PHA9

- GE Fluorescent lamp (F54W/T5/835/ECO)—54W

Technical Specs

Item	Linear Fluorescent Lamp	Start Type	Rapid
Lamp Shape	T5	Initial Lumens	5000
Base Type	Miniature Bi-Pin (G5)	Mean Lumens	4700
Length	45.2"	Shatter Resistance	No
Diameter	5/8"	Primary Application	General Purpose
Watts	54	Lamp Designation	F54T5/835/ECO/HO
Average Life	30,000 hr.	Standards	Meets 2012 Lighting Legislation Energy
Lamp Tone	Neutral	Case Quantity	40
Color Temp.	3500K	Green Environmental Attribute	Product Contributes to Reducing Energy Consumption
CRI	85		

http://www.grainger.com/product/GE-LIGHTING-Fluorescent-Linear-Lamp-5AE34

- GE Fluorescent lamp (F24W/T5/835/ECO)—24W

Technical Specs

Item	Linear Fluorescent Lamp	Start Type	Rapid
Lamp Shape	T5	Min. Starting Temp.	-4 Degrees F
Base Type	Miniature Bi-Pin (G5)	Initial Lumens	2000
Length	21.6"	Mean Lumens	1840
Diameter	5/8"	Shatter Resistance	No
Watts	24	Primary Application	General Purpose
Average Life	30,000 hr.	Lamp Designation	F24T5/835/ECO/HO
Lamp Tone	Neutral	Standards	Meets 2012 Lighting Legislation Energy
Color Temp.	3500K	Case Quantity	40
CRI	85	Green Environmental Attribute	Product Contributes to Reducing Energy Consumption

http://www.grainger.com/product/GE-LIGHTING-Fluorescent-Linear-Lamp-5AE25

- GE compact Fluorescent lamp (F26TBX/841/A/ECO)—26W

Technical Specs

Item	Plug-In CFL	Mean Lumens	1530
Overall Lamp Shape	T	Color Temp.	4100K
Dimmable / Non-Dimmable	Dimmable	Average Life	17,000 hr.
Lamp Type	Triple Tube	CRI	82
Incandescent Equivalent (Watts)	100	Min. Starting Temp.	32 Degrees F
Watts	26	Lamp Designation	F26TBX/A/ECO
Base Type	4-Pin (GX24Q-3)	Start Type	Rapid
Lamp Shape	T4	Footnotes	1,2,6
Lamp Tone	Cool	Standards	Meets 2012 Lighting Legislation Energy
Max. Overall Length	5-1/4"	Primary Application	General Purpose
Shatter Resistance	No	Green Environmental Attribute	Product Contributes to Reducing Energy Consumption
Initial Lumens	1800		

http://www.grainger.com/product/1PHA1?gclid=CNX_5o_R3bwCFVFo7Aodmh8ABA&cm_mmc=PPC:GooglePLA-_-Lighting-_-Lamps-_-1PHA1&ci_src=17588969&ci_sku=1PHA1&ef_id=Uwd4jwAABe3gdWRf:20140221162529:s

- GE Fluorescent lamp (F26DBX/835/ECO4P)—26W

Technical Specs

Item	Plug-In CFL	Mean Lumens	1530
Overall Lamp Shape	T	Color Temp.	3500K
Dimmable / Non-Dimmable	Dimmable	Average Life	17,000 hr.
Lamp Type	Double Tube	CRI	82
Incandescent Equivalent (Watts)	100	Min. Starting Temp.	32 Degrees F
Watts	26	Lamp Designation	F26DBX/ECO4P
Base Type	4-Pin (G24Q-3)	Start Type	Rapid
Lamp Shape	T4	Footnotes	1,2,6
Lamp Tone	Neutral	Standards	Meets 2012 Lighting Legislation Energy
Max. Overall Length	6-3/8"	Primary Application	General Purpose
Shatter Resistance	No	Green Environmental Attribute	Product Contributes to Reducing Energy Consumption
Initial Lumens	1800		

http://www.grainger.com/product/GE-LIGHTING-Plug-In-CFL-1PGY6

- GE Fluorescent lamp (F8T5/CW)—8W

Technical Specs

Item	Linear Fluorescent Lamp	Start Type	Preheat
Lamp Shape	T5	Initial Lumens	400
Base Type	Miniature Bi-Pin (G5)	Mean Lumens	320
Length	12"	Shatter Resistance	No
Diameter	5/8"	Primary Application	General Purpose
Watts	8	Lamp Designation	F8T5/CW/HO
Average Life	5000 hr.	ANSI Code	2003-1
Lamp Tone	Cool	Standards	Meets 2012 Lighting Legislation Energy
Color Temp.	4100K	Case Quantity	24
CRI	60		

http://www.grainger.com/product/GE-LIGHTING-Fluorescent-Linear-Lamp-2V235

Appendix G: East Hall Survey Responses

East Hall Final Report

Last Modified: 01/13/2014

1. Which floor do you live on?

#	Answer		Response	%
1	East 2		9	39%
2	East 3		13	57%
3	East 4		1	4%
4	East 5		0	0%
	Total		23	100%

2. At what temperature do you feel comfortable in the winter?

#	Answer	Min Value	Max Value	Average Value	Standard Deviation	Responses
1	Click to write Choice 1	65.00	75.00	70.44	3.22	18

3. How many people are there in your suite?

#	Answer		Response	%
1	Single (Studio) Apartment		1	4%
2	4		22	96%
	Total		23	100%

4. How long have you been living in East Hall? (academic years)

#	Answer		Response	%
1	Less than one year.		13	57%
2	One year.		1	4%
3	Two years.		9	39%
4	Three years.		0	0%
5	More than three years.		0	0%
	Total		23	100%

5. Are you familiar with the energy saving features in East Hall?

#	Answer		Response	%
1	Very familiar		4	17%
2	Somewhat familiar		16	70%
3	Not familiar		3	13%
	Total		23	100%

6. On average, how many hours do you spend in East Hall each day?

#	Answer	Min Value	Max Value	Average Value	Standard Deviation	Responses
1	Weekday	6.00	20.00	13.04	3.72	23
2	Weekend	5.00	24.00	15.65	5.42	23

7. How would you define the role of the dorm? (check all apply)

#	Answer		Response	%
1	Rest/Sleeping		23	100%
2	Studying		19	83%
3	Entertainment		17	74%
4	Dining (including cooking)		17	74%
5	Other (please specify)		3	13%

Other (please specify)
Homework
Methalab
socializing

8. Overall, do you consider yourself to be an efficient user of energy?

#	Answer		Response	%
1	Yes		2	9%
2	Somewhat		17	74%
3	No		4	17%
	Total		23	100%

9. Overall, do you consider East Hall to be energy efficient?

#	Answer		Response	%
1	Yes		16	70%
2	No		1	4%
3	Not sure		6	26%
	Total		23	100%

10. Overall, do you consider East Hall to be a comfortable place to live?

#	Answer		Response	%
1	Yes		17	74%
2	No		2	9%
3	Somewhat		4	17%
	Total		23	100%

11. Considering the AC in room, how do you feel during summer?

#	Answer		Response	%
1	Very cold		1	4%
2	Somewhat cold		3	13%
3	Comfortable		11	48%
4	Somewhat hot		8	35%
5	Very hot		0	0%
	Total		23	100%

12. Please comment on your satisfaction/dissatisfaction with the heating/cooling system. Do you have enough control? are there ways you feel it could be improved?

Text Response
I swear the AC wasn't adjusting during the summer. I tried to reduce the AC because I was getting cold (that, and it's inefficient), but no dice.
you should be able to turn off the blower. the singles don't have sensors on the windows so the fan ALWAYS blows and despite the temperature it's set to its always cold because of the draft
The controls of the system don't make sense since the thermostat is the only controler and doesn't work well.
I really wish there were windows in the kitchen/living room
I've had difficulty controlling the thermostat - it seems like it doesn't actually do anything, and opening/closing the windows didn't have any effect on the AC
I would like to be able to turn off the A/C. One morning the sun was shining on the thermostat so the A/C was blasting and we were cold. We had to open a window to the colder outside air to get the A/C to turn off. Also, when we're all home and in our rooms working for several hours the heat will turn off because and we sometimes get cold.
Such hot, much cold, so AC, WOW
should be cooler in summer. Should be able to adjust fan speeds desired
Control is a placebo, it could be improved by extending the range and having something other than dummy units on the walls.
We do not have enough control of the heat/AC. The rooms take too long to become comfortable because they either take too long to heat up or cool down. In the case of the AC, it also does not get cool enough to be comfortable.
The suite hearts unevenly. My room terms to be chilly while the double is pretty warm.
there is no heat, the air coming out of the vents are cold. The thermostat read 64 degrees this morning.

Statistic	Value
Total Responses	12

13. What temperature do you set for the AC in summer?

#	Answer	Min Value	Max Value	Average Value	Standard Deviation	Responses
1		69.00	73.00	70.29	1.45	17

14. At what temperature do you feel comfortable in the summer?

#	Answer	Min Value	Max Value	Average Value	Standard Deviation	Responses
1		65.00	74.00	69.74	2.42	19

15. Considering the heating in the room, how do you feel during winter?

#	Answer		Response	%
1	Very cold		1	4%
2	Somewhat cold		10	43%
3	Comfortable		6	26%
4	Somewhat hot		6	26%
5	Very hot		0	0%
	Total		23	100%

16. Have you ever opened windows during winter due to overheating in room?

#	Answer		Response	%
1	Yes		9	39%
2	No		14	61%
	Total		23	100%

17. How often do you have to open the windows due to overheating?

#	Answer		Response	%
1	less than once a week		5	63%
2	2-3 times a week		1	13%
3	4-5 times a week		0	0%
4	always		2	25%
	Total		8	100%

18. How long do you usually leave the windows open?

#	Answer		Response	%
1	less than 5 minutes		0	0%
2	less than 1 hour		2	25%
3	1-3 hours		2	25%
4	half a day		2	25%
5	always		2	25%
	Total		8	100%

19. How long does it usually take for the room to heat up to your desired temperature?

#	Answer		Response	%
1	Less than 10 minutes		3	15%
2	10-30 minutes		2	10%
3	More than 30 minutes		4	20%
4	Unsure		11	55%
	Total		20	100%

20. What temperature do you set for the heat in the winter?

#	Answer	Min Value	Max Value	Average Value	Standard Deviation	Responses
1	Click to write Choice 1	69.00	73.00	71.31	1.62	16

21. Do you cook in East Hall?

#	Answer		Response	%
1	Yes		17	85%
2	No		3	15%
	Total		20	100%

22. Do you have sufficient lighting in your suite?

#	Answer		Response	%
1	Yes		15	75%
2	No		5	25%
	Total		20	100%

23. Could you specify locations that are well-lit and others that are not well-lit?

Text Response
Kitchen needs more light at night. Everywhere else is fine.
Kitchen
kitchen is not lit well
My methlab is not well lit. Can't see all the different drugs I mix. Some times i make mistakes. Customers don't like that...
sometimes use desk light.
My room is well lit, the closests and main room are not.
Bathroom is well lit. Bedroom is borderline. Kitchen could definitely use more lights for at night.
My room often feels dark.
well lit: living room, sinks. poor lighting: kitchen, room

Statistic	Value
Total Responses	9

24. Do you feel the need to use additional lighting anywhere in your suite?

#	Answer		Response	%
1	Yes		7	35%
2	No		13	65%
	Total		20	100%

25. Do you usually tend to leave the following devices on when they are not being used?

#	Question	Yes	No	Total Responses	Mean
1	TV	3	17	20	1.85
2	Laptop Computer	10	10	20	1.50
3	Desktop Computer	5	13	18	1.72
4	Game console	0	17	17	2.00
5	Lights	5	15	20	1.75

26. When your windows are closed, do you feel a draft?

#	Answer		Response	%
1	Always		1	5%
2	Many times		2	10%
3	Sometimes		2	10%
4	Rarely		8	38%
5	Never		7	33%
6	Unsure		1	5%
	Total		21	100%

27. How full is your fridge?

#	Answer		Response	%
1	Full		5	25%
2	Medium		14	70%
3	Empty		1	5%
	Total		20	100%

28. Overall, do you have any comments or suggestions on lighting?

Text Response
I don't know the types of bulbs being used, but if they aren't fluorescent or better, they should be.
Maybe a standing light for the common room would b nice
Many of the rooms are lit by one or two lights, so if just one light goes out makes a big difference. (It's happened once this year). It might be nice if we could go down to res services to get a replacement lightbulb or something so we don't have to wait for a work order to go through.
Much light. Such color. So visible. WOW
brighter lights.
location, my head creates a constant shadow on my desk when working. there is also no lighting by the door or by the counter

Statistic	Value
Total Responses	6

29. On average, how often do you use the following electric appliances

#	Question	Less than once a week	1-2 times a week	3-4 times a week	Almost Everyday	Everyday	Not Applicable	Total Responses	Mean
1	Television	3	4	3	1	6	3	20	3.60
2	Laptop Computer	0	3	0	0	16	1	20	4.60
3	Desktop Computer	0	0	0	1	6	13	20	5.60
4	Game Console	4	0	1	1	1	13	20	4.70
5	Hair styling tools	2	0	0	0	0	18	20	5.50
6	Stereo/Home audio equipment	1	2	1	2	2	12	20	4.90
7	Stove/Range	3	2	1	9	4	1	20	3.60
8	Microwave	2	2	3	10	2	1	20	3.55
9	Other kitchen appliance	2	2	2	3	4	7	20	4.30
10	Printer	5	4	2	1	0	8	20	3.55
11	Fan	1	2	1	1	2	13	20	5.00
12	Device chargers	0	1	1	1	15	2	20	4.80

30. How often do you open the fridge door?

#	Answer		Response	%
1	Never		0	0%
2	1-2 Times a day		4	20%
3	3-5 Times a day		6	30%
4	6-10 Times a day		8	40%
5	More than 10 times a day		2	10%
	Total		20	100%

31. How often do you cook?

#	Answer		Response	%
1	Less than Once a Month		2	11%
2	Once a Month		1	5%
3	2-3 Times a Month		1	5%
4	Once a Week		1	5%
5	2-3 Times a Week		3	16%
6	Daily		3	16%
7	Multiple times per day		8	42%
	Total		19	100%

32. What do you usually prefer to use to cook, microwave or stove?

#	Answer		Response	%
1	Microwave		2	11%
2	Stove/Range		4	21%
3	Both		12	63%
4	Other (Please specify)		1	5%
	Total		19	100%

Other (Please specify)
Toaster oven (but not by much)

33. Do you consider it necessary that everyone should save energy?

#	Answer		Response	%
1	Yes		12	60%
2	No		2	10%
3	I don't care		6	30%
	Total		20	100%

34. Among the following electric appliances, which ones do you have in your suite?

#	Answer		Response	%
1	Television		17	85%
2	Laptop Computer		19	95%
3	Desktop Computer		7	35%
4	Game Console		7	35%
5	Hair styling tools		2	10%
6	Stereo/Home audio equipment		9	45%
7	Microwave		20	100%
8	Other Kitchen Appliance (not provided by WPI)		12	60%
9	Printer		11	55%
10	Fan		6	30%
11	Device chargers		20	100%

35. On average, how much electric energy in kWh do you think you use every day?

Text Response
I don't have the foggiest idea
15
No idea at all
No idea. Average probably
I don't know.
idk, depends on how much Meth is made. Some days i'll use a lot some days not so much.
Unknown
A lot

Statistic	Value
Total Responses	8

36. Which electronics are plugged in at all times, regardless of being in use or not

#	Answer		Response	%
1	TV		16	80%
2	laptop		11	55%
3	desktop		7	35%
4	gaming system		4	20%
5	extra lights		7	35%
6	stereo system		6	30%
7	kitchen appliances		14	70%
8	printer		7	35%
9	personal mini fridge		5	25%
10	fan		6	30%
11	Device charger		16	80%

37. Do you have any suggestions that may be helpful in improving this survey?

Text Response
as someone who completed iqp already, this survey is way too long and for those who start it many will stop halfway throughout
Much time, Such waste, So long, WOW
Include water usage questions, if that is applicable to the IQP
ask why i choose not to conserve any enegy in east when i fully support saving enegy, and the reason is i feel like im getting gyped. i pay so much for zero heat

Statistic	Value
Total Responses	4

Appendix H: Founders Hall Survey Responses

Founders Hall Final Report

Last Modified: 12/16/2013

1. Which floor do you live on?

#	Answer		Response	%
1	Founders 1		3	14%
2	Founders 2		4	18%
3	Founders 3		10	45%
4	Founders 4		5	23%
	Total		22	100%

2. How many people are there in your suite?

#	Answer		Response	%
1	2		0	0%
2	4		9	43%
3	6		12	57%
	Total		21	100%

3. How long have you been living in Founders Hall? (academic years)

#	Answer		Response	%
1	Less than one year.		20	91%
2	One year.		2	9%
3	Two years.		0	0%
4	Three years.		0	0%
5	More than three years.		0	0%
	Total		22	100%

4. Overall, do you consider yourself to be an efficient user of energy?

#	Answer		Response	%
1	Yes		5	23%
2	No		6	27%
3	Somewhat		11	50%
	Total		22	100%

5. On average, how many hours do you spend in Founders Hall each day?

#	Answer	Min Value	Max Value	Average Value	Standard Deviation	Responses
1	Weekday	3.00	18.00	13.33	3.88	21
2	Weekend	8.00	24.00	15.86	4.96	21

6. How would you define the role of the dorm? (check all that apply)

#	Answer		Response	%
1	Rest/Sleeping		22	100%
2	Studying		18	82%
3	Entertainment		13	59%
4	Dining		13	59%
5	Other (please specify)		0	0%

7. Overall, do you consider Founders Hall to be energy efficient?

#	Answer		Response	%
1	Yes		2	10%
2	No		11	52%
3	Somewhat		8	38%
	Total		21	100%

8. Overall, do you consider Founders Hall to be a comfortable place to live?

#	Answer		Response	%
1	Yes		16	76%
2	No		0	0%
3	Somewhat		5	24%
	Total		21	100%

9. Considering the heating in the room, how do you feel during winter?

#	Answer		Response	%
1	Very cold		1	5%
2	Somewhat cold		3	14%
3	Comfortable		11	52%
4	Somewhat hot		6	29%
5	Very hot		0	0%
	Total		21	100%

10. Have you ever opened the windows during the winter due to overheating in your room?

#	Answer		Response	%
1	Yes		10	48%
2	No		11	52%
	Total		21	100%

11. How often do you have to open the windows due to overheating?

#	Answer		Response	%
1	Less than once a week		6	67%
2	2-3 times a week		1	11%
3	4-5 times a week		1	11%
4	Everyday		1	11%
	Total		9	100%

12. How long do you usually leave the windows open?

#	Answer		Response	%
1	Less than 5 minutes		2	22%
2	Less than 1 hour		5	56%
3	1-3 hours		1	11%
4	Half a day		1	11%
5	Always		0	0%
	Total		9	100%

13. When your windows are closed, do you feel a draft?

#	Answer		Response	%
1	Always		4	20%
2	Many times		1	5%
3	Sometimes		5	25%
4	Rarely		7	35%
5	Never		2	10%
6	Unsure		1	5%
	Total		20	100%

14. How long does it usually take for the room to heat up to your desired temperature?

#	Answer		Response	%
1	Less than 10 minutes		5	25%
2	10-30 minutes		6	30%
3	More than 30 minutes		4	20%
4	Unsure		5	25%
	Total		20	100%

15. What temperature do you set for the heat in the winter?

#	Answer	Min Value	Max Value	Average Value	Standard Deviation	Responses
1	Degrees	60.00	80.00	71.05	6.51	19

16. At what temperature do you feel comfortable in the winter?

#	Answer	Min Value	Max Value	Average Value	Standard Deviation	Responses
1	Degrees	65.00	80.00	70.05	3.49	20

17. Please comment on your satisfaction/dissatisfaction with the heating system. Do you have enough control? Are there ways you feel it could be improved?

Text Response
The heating system is kind of overboard; I can make it uncomfortably warm to the point of sweating in my room.
The larger problem is my roommates changing the heat to either too hot or too cold.
The thermostat will often read a higher temperature than it actually is. If we set it to 70 it will turn off around 65 because it reads 70. Also because of the draft in the personal rooms, the rooms will be colder than the common room where the thermostat is.
thermostat is for the whole suite and while the hallway might be warm our rooms are still cold.
Windows leak a lot; shades are always closed to conserve heat, but now don't let in any light; room is almost always too cold; heater is under bed, need fan to push heat out from under bed; disputes with roommates because doubles are always cold while singles are too hot
I wish we could control the bedrooms separately.
My room is a sauna once the heat is turned on
Wish each room within a suite could control their own room, as opposed to one thermostat in the common area
I am satisfied with the heating system.
I think it works great, just wish there was more control for individual rooms
We have ours on the lowest setting in my suite and we still walk in and like immediately start sweating
I didn't realize we had control. Our triple doesn't appear to have a thermostat, but overall I am never cold in my room. Common rooms for the floor are different. The heaters in there never seem to work correctly. It is either too hot or too cold in there.

Statistic	Value
Total Responses	12

18. Do you have sufficient lighting in your suite?

#	Answer		Response	%
1	Yes		8	42%
2	No		11	58%
	Total		19	100%

19. Could you specify locations that are well-lit and others that are not well-lit?

Text Response
zxc
The doubles could be more well lit, had to bring in extra lamp
In the common room we need more light in the other side of the room.
everywhere but my room is well lit. my room is only lit on one side
closet area = well-lit, desk/work area = not so well-lit
The rooms only have one light that's too harsh, so I usually use a lamp instead.
closet is well-lit, bedroom in the double is not well-lit. the common room is omly well-lit now becaude we brought in our own lamp.
Nothing is not well lit.
doubles are not well lit
the closet is well lit, bed not so much
Not well lit: area right in front of main door, end of hallway (can't see door handle/keyhole to room at night because hallway light is too bright and kept off)
My light is located directly above the closet, and I do not have a built in desk-light.
the light is skewed to one side of the room, so the other side doesn't really get much
The common area is well lit but the bedrooms aren't
Room is only lit over closet
All the rooms are well-lit in founders.
not well lit neat the main door and on the opposite wall from the lights in the doubles
Everything is pretty well lit.
In a triple that is L-shaped, only the area by the door is well lit at all. The rest of the room, especially the part around the corner from the door, is not well lit at all.

Statistic	Value
Total Responses	19

20. Do you feel the need to use additional lighting anywhere in your suite?

#	Answer		Response	%
1	Yes		15	75%
2	No		5	25%
	Total		20	100%

21. Overall, do you have any comments or suggestions on lighting?

Text Response
zx
Extra lighting in the doubles
more lamps
more lights
it is too dark.
Dimmers in bathroom and hallway would be great (or dimmers overall); have additional light right above the main door in the living room; separate lightswitches for sink room and shower room; lights above desk in double room are way too harsh, so we use a separate lamp instead
it would be great to move the light fixtures to the center of the room
The one light over the closet is no enough for my bedroom
we need two lamps for the common room
I only need additional lighting right next to my bed as I'm in a corner of the room.

Statistic	Value
Total Responses	10

22. Do you have any suggestions that may be helpful in improving this survey?

Text Response
no
no
Nah.
the kW/h part is a little obscure for those who may not be familiar with the units, also i answered all the questions based on it being winter time
There are suites with 5 people in them. Mine is one of them. I also have a friend who has an 8-person suite.

Statistic	Value
Total Responses	5

23. How often do you open the fridge door?

#	Answer		Response	%
1	Never		3	15%
2	1-2 Times a day		13	65%
3	3-5 Times a day		4	20%
4	6-10 Times a day		0	0%
5	More than 10 times a day		0	0%
	Total		20	100%

24. How full is your fridge?

#	Answer		Response	%
1	Full		7	35%
2	Medium		13	65%
3	Empty		0	0%
	Total		20	100%

25. Among the following electric appliances, which ones do you own?

#	Answer		Response	%
1	Television		10	50%
2	Laptop Computer		18	90%
3	Desktop Computer		6	30%
4	Game Console		10	50%
5	Hair styling tools		9	45%
6	Stereo/Home audio equipment		8	40%
7	Microwave		11	55%
8	Other Kitchen Appliances (not provided by WPI)		4	20%
9	Printer		10	50%
10	Fan		13	65%
11	Device chargers		19	95%

Other Kitchen Appliances (not provided by WPI)
Keurig
Electric tea kettle
Toaster oven
small fridge

26. On average, how often do you use the following electric appliances?

#	Question	Less than once a week	1-2 times a week	3-4 times a week	Almost Everyday	Everyday	Not Applicable	Total Responses	Mean
1	Television	3	3	4	0	4	6	20	3.85
2	Laptop Computer	1	1	1	0	15	2	20	4.65
3	Desktop Computer	0	1	0	1	5	13	20	5.45
4	Game Console	3	3	2	1	1	10	20	4.20
5	Hair Styling tools	3	3	4	0	0	10	20	4.05
6	Stereo/Home audio equipment	3	2	0	2	2	11	20	4.55
7	Microwave	5	5	7	2	0	1	20	2.50
8	Other kitchen appliances	2	2	4	0	0	12	20	4.50
9	Printer	4	4	2	0	1	9	20	3.85
10	Fan	5	3	1	4	0	6	19	3.47
11	Device chargers	0	1	1	2	14	1	19	4.68

27. Do you consider it necessary that everyone should save energy?

#	Answer		Response	%
1	Yes		16	80%
2	No		2	10%
3	I don't care		2	10%
	Total		20	100%

28. On average, how much energy in kWh do you think you use everyday?

Text Response
xcx
no idea
6
I don't know how much a kWh is, but less than average for someone who lives in Founders.
I do not know.
No clue
unsure
No clue.
Not sure how to measure.
200
6
5
I have no idea
I have no idea. I don't really know how to gauge it without an actual readout of the energy each thing uses.

Statistic	Value
Total Responses	14

29. Do you usually tend to leave the following devices on when they are not being used?

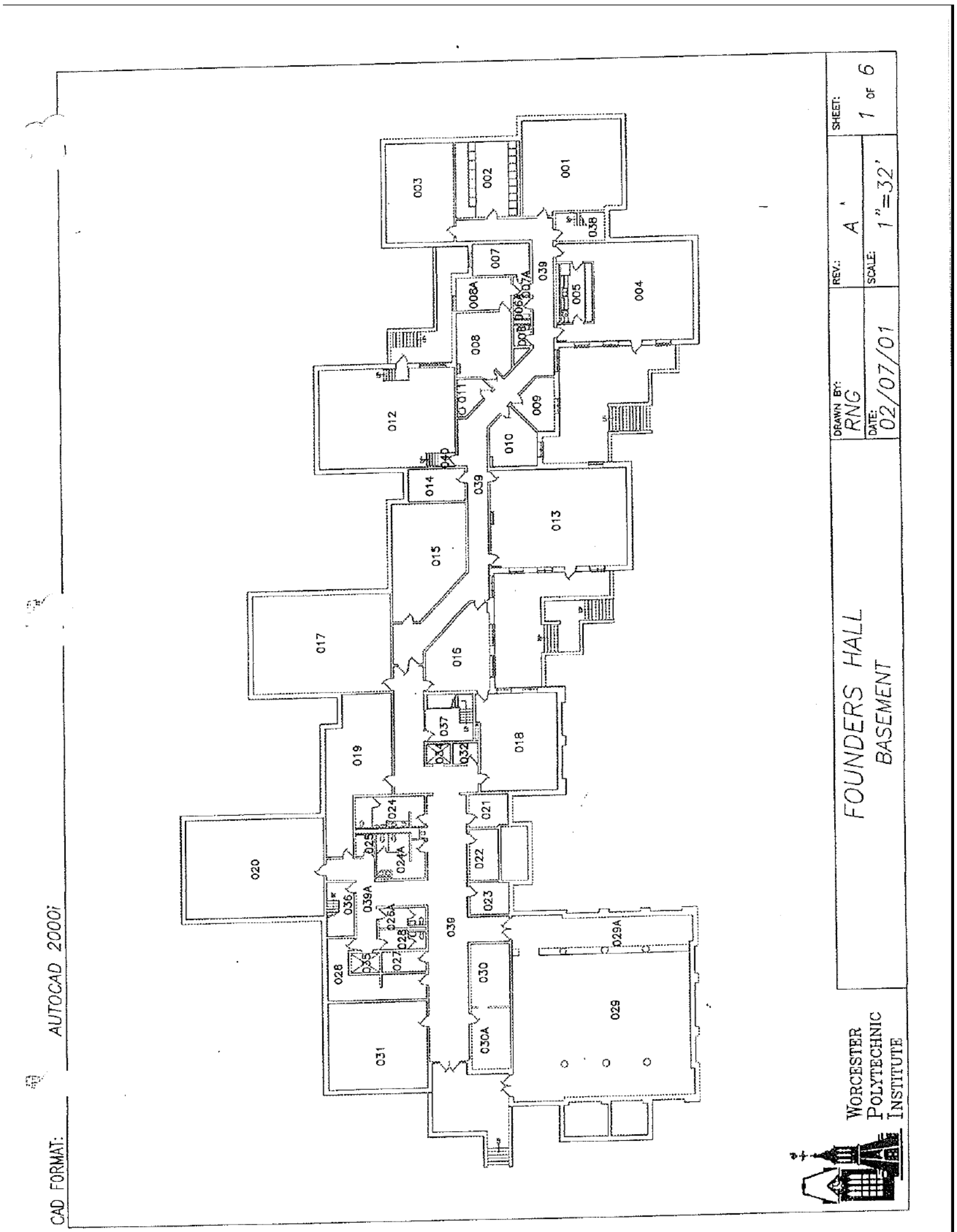
#	Question	Yes	No	Total Responses	Mean
1	TV	2	17	19	1.89
2	Laptop Computer	10	9	19	1.47
3	Desktop Computer	3	17	20	1.85
4	Game Console	0	19	19	2.00
5	Lights	5	15	20	1.75

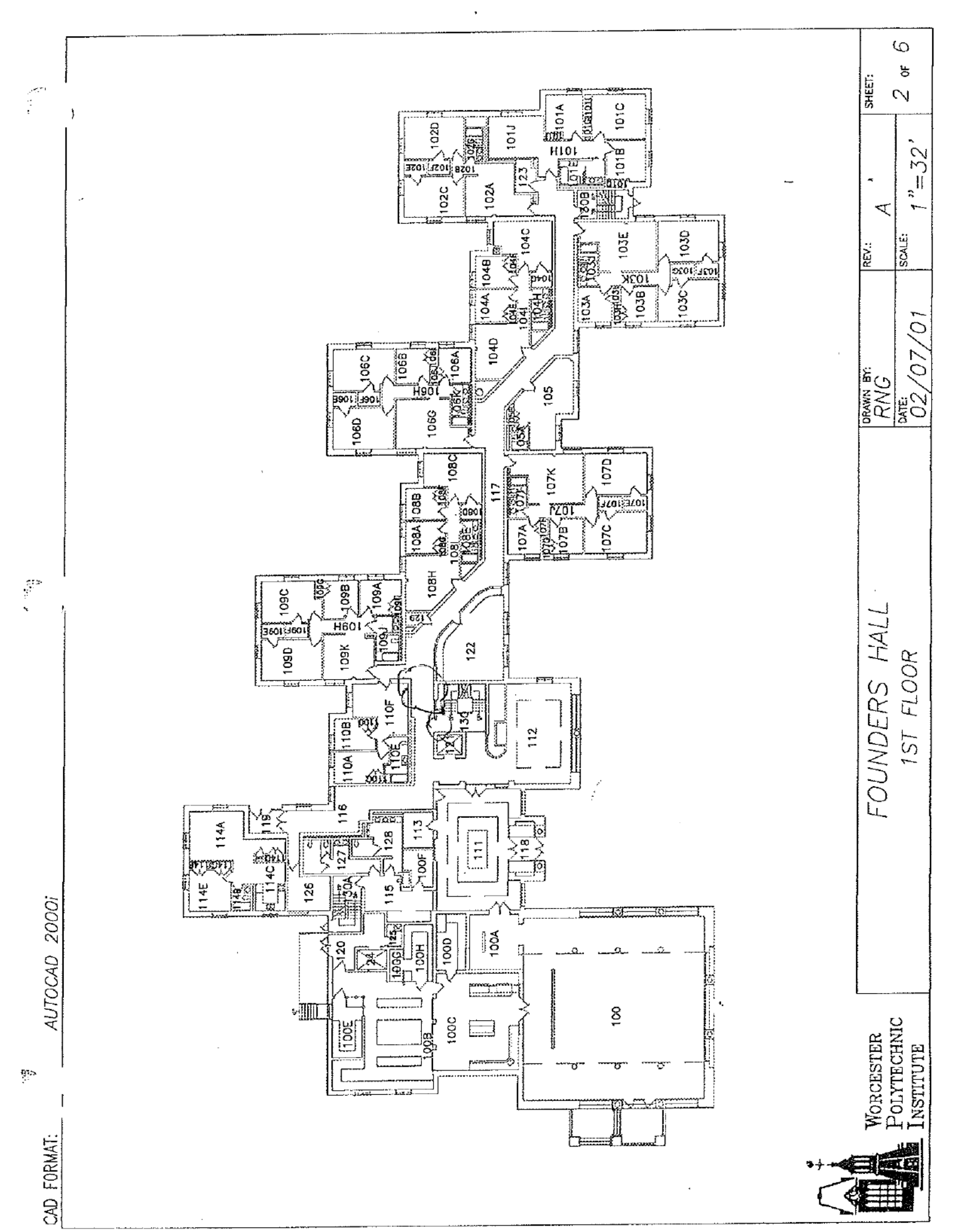
30. Which of the following electronics are plugged in at all times, regardless of being in use or not?

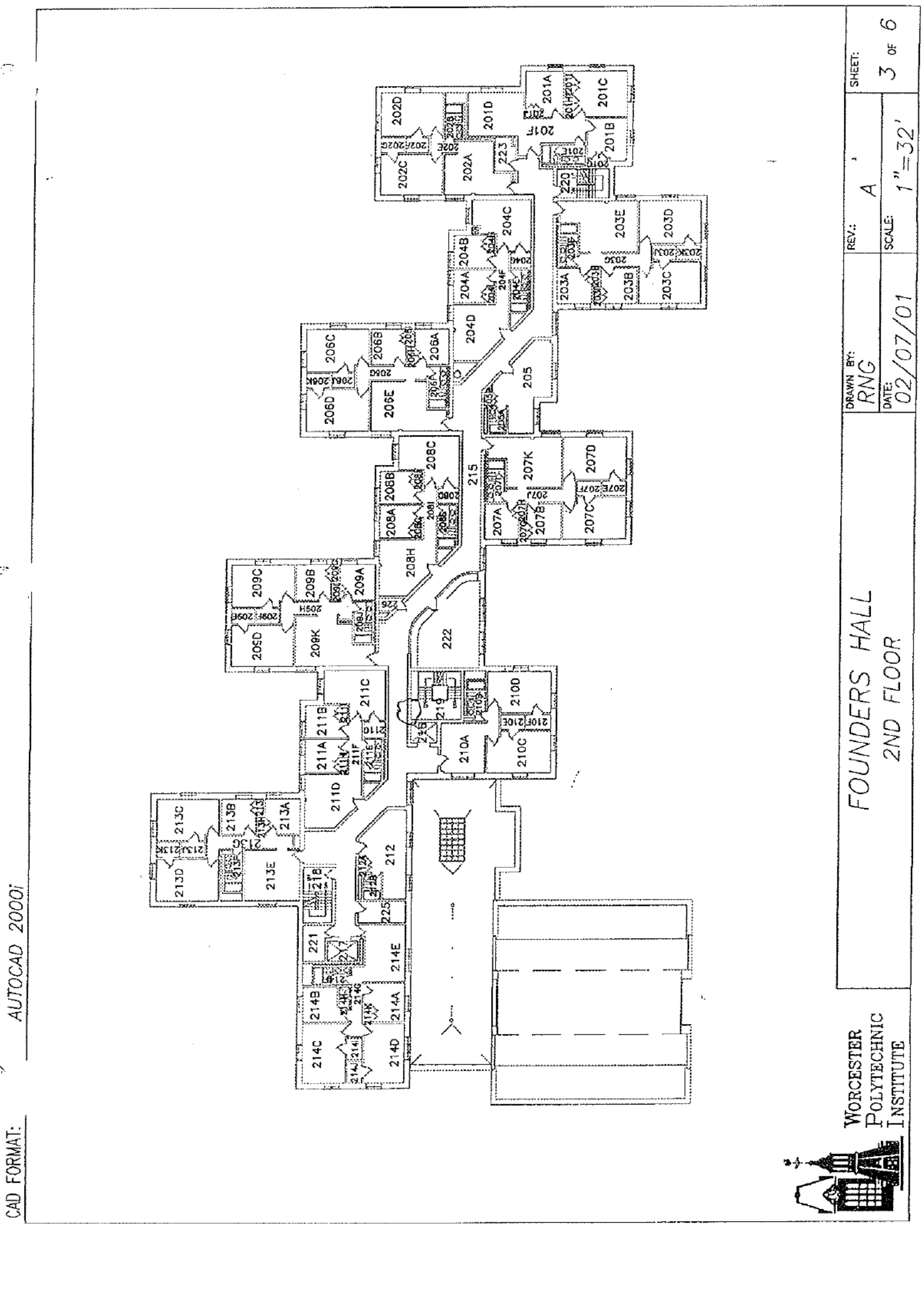
#	Answer		Response	%
1	TV		9	45%
2	Laptop Computer		12	60%
3	Desktop Computer		7	35%
4	Game Console		6	30%
5	Extra Light		15	75%
6	Stereo System		7	35%
7	Kitchen Appliances		9	45%
8	Printer		9	45%
9	Personal Mini Fridge		3	15%
10	Fan		9	45%

Appendix I: Floor Plans

I.1: Founders Hall Floor Plan




CAD FORMAT: AUTOCAD 2000i
WORCESTER POLYTECHNIC INSTITUTE
FOUNDERS HALL
1ST FLOOR
DRAWN BY: RNG
DATE: 02/07/01
REV.: A
SCALE: 1"=32'
SHEET: 2 of 6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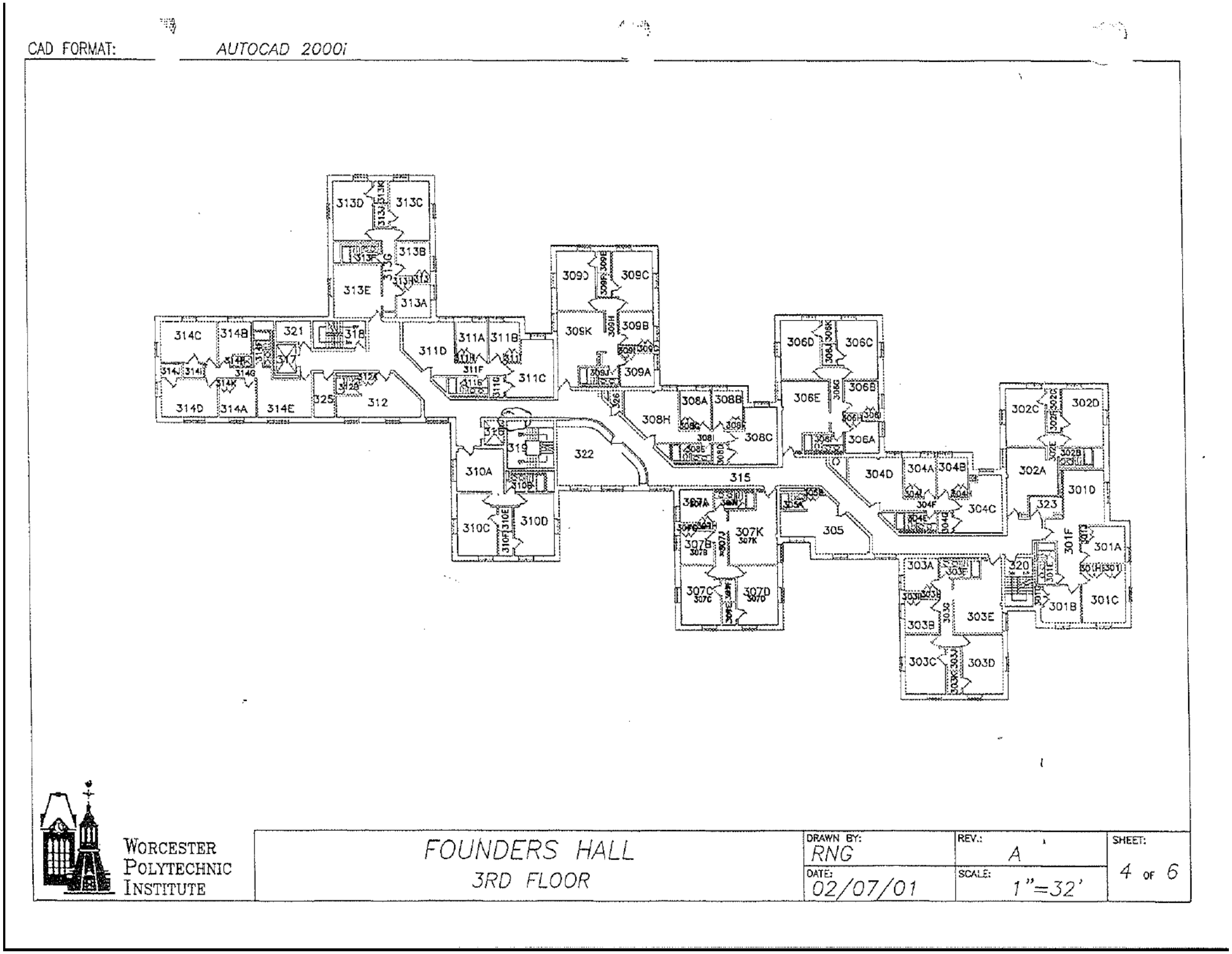
AUTOCAD 2000i
FOUNDERS HALL
2ND FLOOR
WORCESTER POLYTECHNIC INSTITUTE
DRAWN BY: RNG
DATE: 02/07/01
REV.: A
SCALE: 1"=32'
SHEET: 3 OF 6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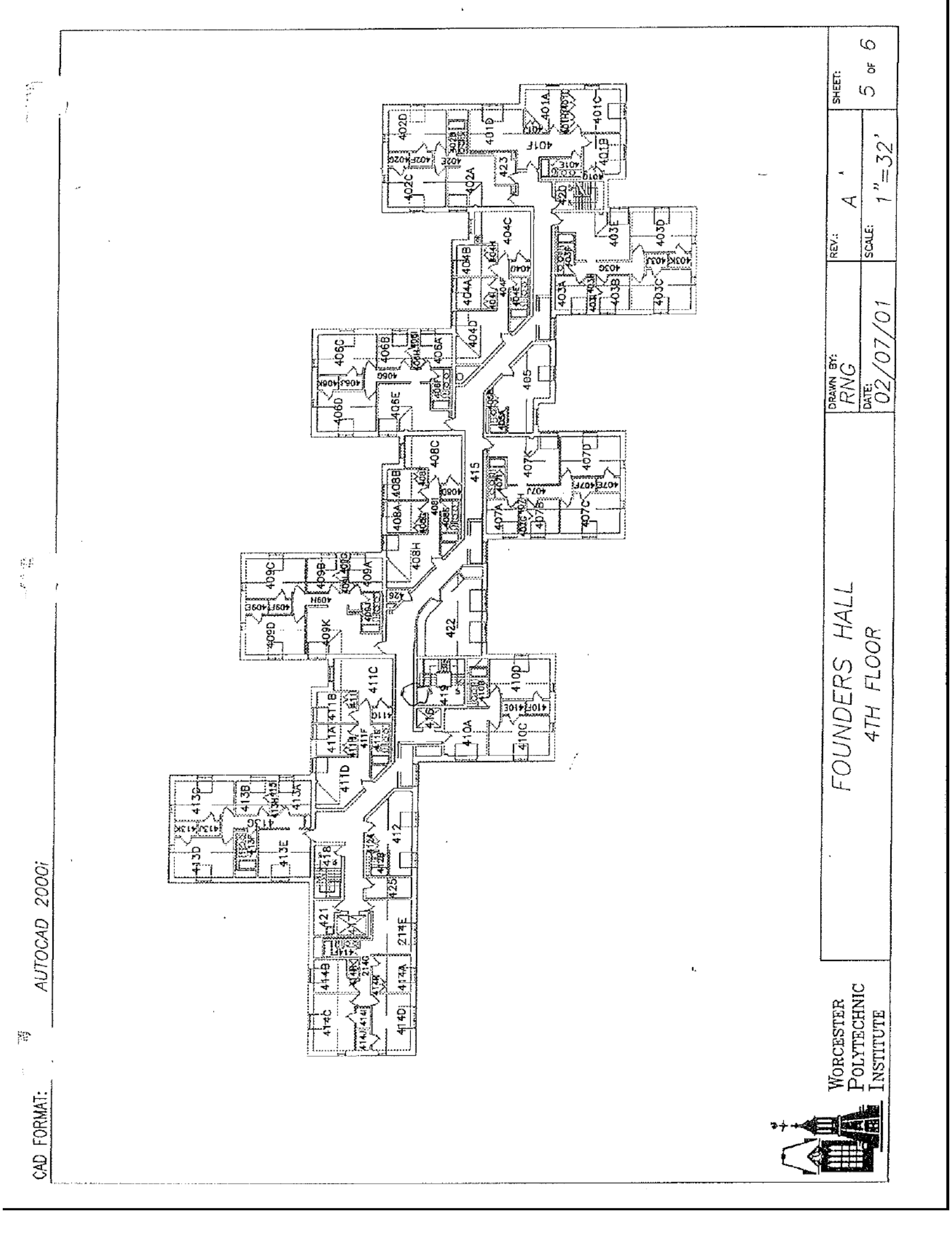
AUTOCAD 2000i
WORCESTER POLYTECHNIC INSTITUTE
FOUNDERS HALL
3RD FLOOR
DRAWN BY: RNG
DATE: 02/07/01
REV.: A
SCALE: 1"=32'
SHEET: 4 of 6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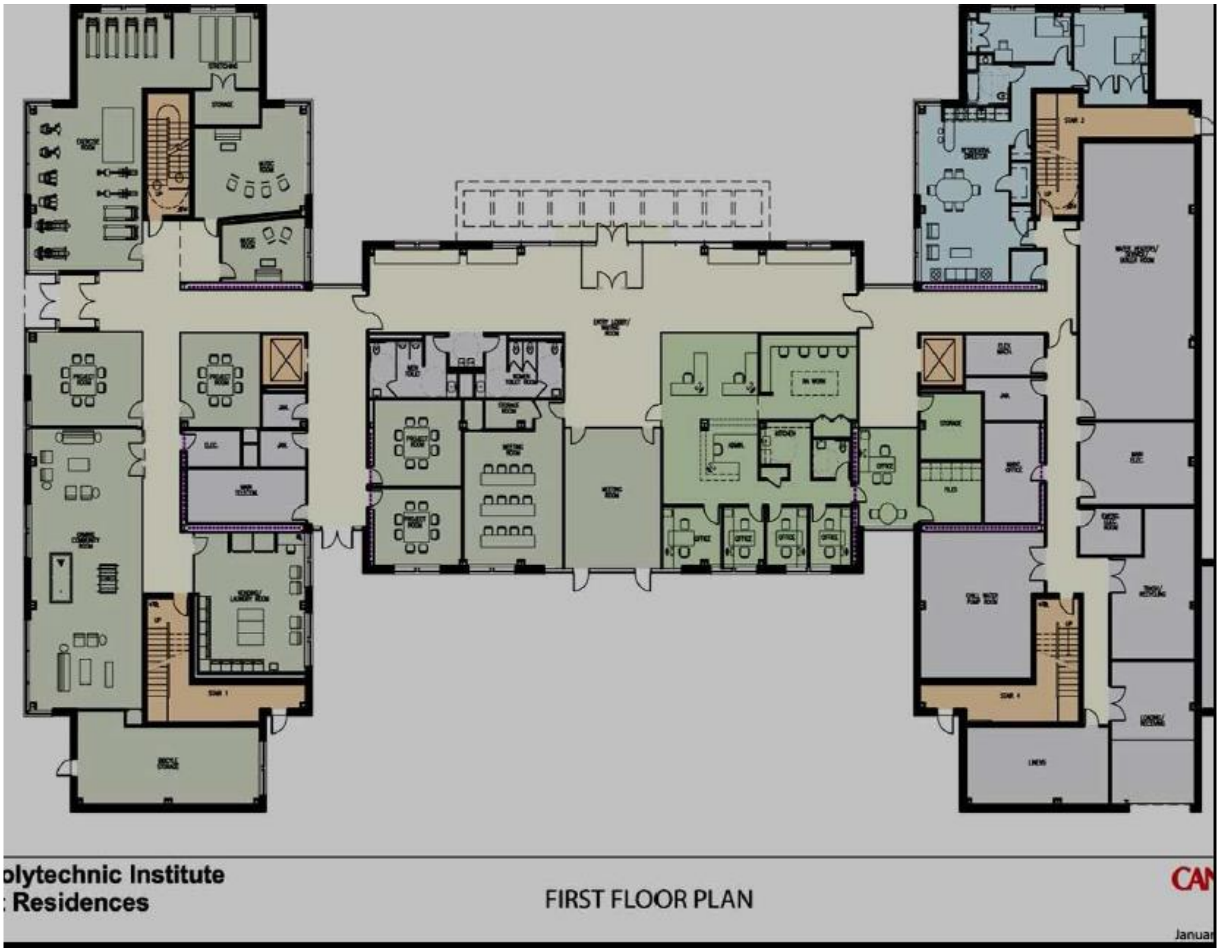
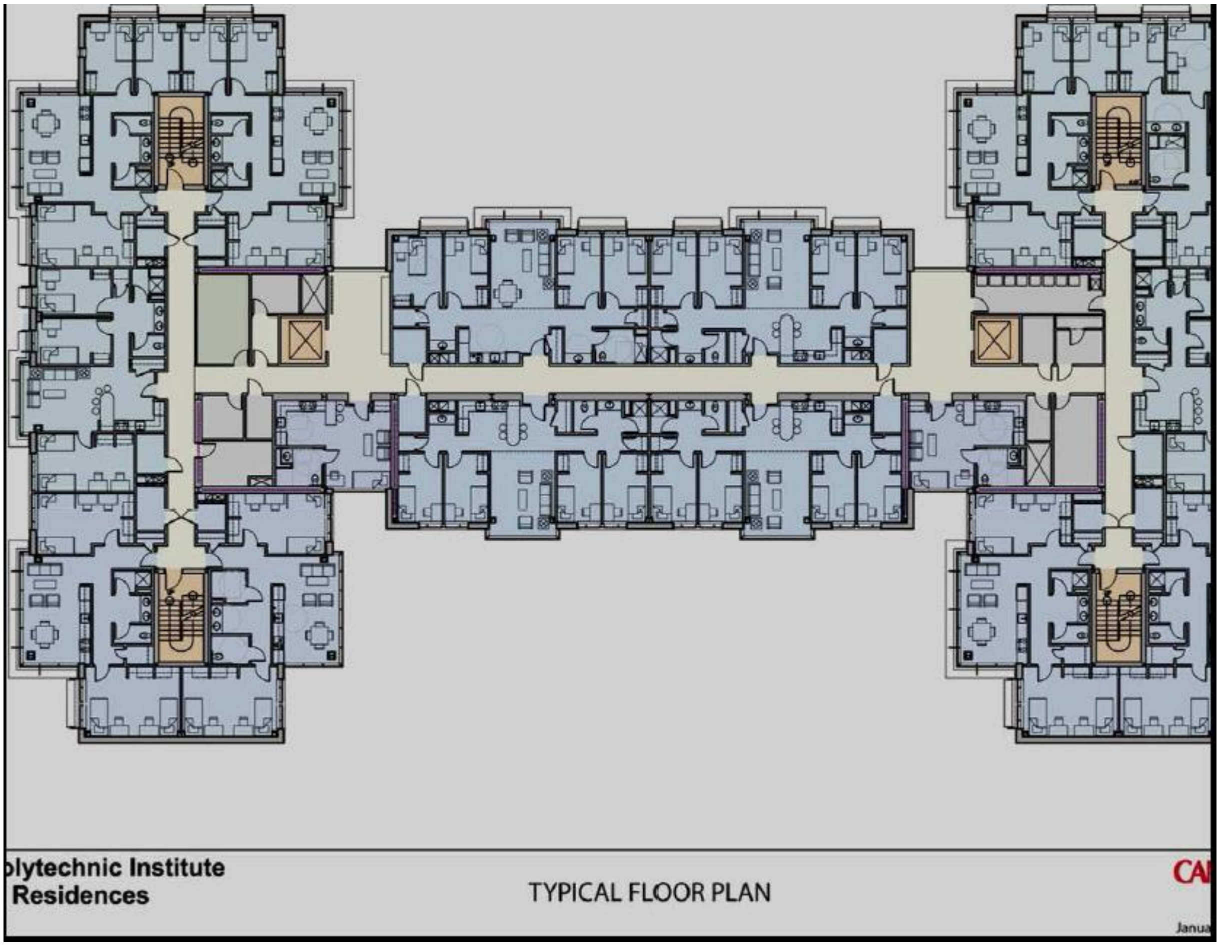
WORCESTER POLYTECHNIC INSTITUTE
FOUNDERS HALL
4TH FLOOR
DRAWN BY: RNG
DATE: 02/07/01
REV.: A
SCALE: 1"=32'
SHEET: 5 OF 6

I.2: East Hall Floor Plans





lytechnic Institute
Residences
TYPICAL FLOOR PLAN

Appendix J: Energy Bills

J.1: National Grid—East Hall

EHS 1

nationalgrid

SERVICE FOR
WORCESTER POLYTECHNIC
30 BOYNTON ST, EAST DORM
WORCESTER MA 01609

BILLING PERIOD
Dec 16, 2013 to Jan 17, 2014

ACCOUNT NUMBER

PLEASE PAY BY
Feb 15, 2014

PAGE 1 of 2

AMOUNT DUE
$ 3,737.52

www.nationalgrid.com
CUSTOMER SERVICE
1-800-322-3223
CREDIT DEPARTMENT
1-888-211-1313
POWER OUTAGE OR DOWNED LINE
1-800-465-1212
EMAIL BILLING INQUIRES
customerservice@us.ngrid.com
CORRESPONDENCE ADDRESS
PO Box 960
Northborough, MA 01532-0960
ELECTRIC PAYMENT ADDRESS
PO Box 11737
Newark, NJ 07101-4737
DATE BILL ISSUED
Jan 22, 2014

Enrollment Information

To enroll with a supplier or change to another supplier, you will need the following information about your account:
Loadzone WCMA
Acct No: 91577-49006 Cycle: 14, WORC

Electric Usage History

Month	kWh	Month	kWh
Jan 13	79400	Aug 13	112000
Feb 13	100200	Sep 13	107400
Mar 13	86200	Oct 13	99800
Apr 13	86000	Nov 13	87800
May 13	89200	Dec 13	96200
Jun 13	90800	Jan 14	83800
Jul 13	116600		

Billed Demand Last 12 months

Minimum	160
Maximum	336
Average	223.8333

ACCOUNT BALANCE

Previous Balance		4,160.76
Payment Received on JAN 13 (*ACH*)	*THANK YOU*	- 4,160.76
Current Charges		+ 3,737.52
	Amount Due ▶	**$ 3,737.52**

To avoid late payment charges of 0.82%, $ 3,737.52 must be received by Feb 15 2014.

➤ **GO PAPERLESS:** You'll help yourself and the environment by signing up to manage your bills online at www.nationalgridus.com/gopaperless.

DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading	-	Previous Reading	=	Difference	x	Meter Multiplier	=	Total Usage
Energy	31929 *Actual*		31510 *Actual*		419		200		83800 kWh
Peak	12772 *Actual*		12609 *Actual*		163		200		32600 kWh
Off Peak	19157 *Actual*		18901 *Actual*		256		200		51200 kWh
							Total Energy		**83800 kWh**
Demand-kW									
Peak							200		160.0 kW
Off Peak							200		156.0 kW
Demand-kVA									
Peak							200		164.0 kVA
Off Peak							200		158.0 kVA

METER NUMBER 05031049 NEXT SCHEDULED READ DATE Feb 19
SERVICE PERIOD Dec 16 - Jan 17 NUMBER OF DAYS IN PERIOD 32
RATE Time-of-Use G-3 VOLTAGE DELIVERY LEVEL 0 - 2.2 kv

KEEP THIS PORTION FOR YOUR RECORDS.
RETURN THIS PORTION WITH YOUR PAYMENT.

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
	Feb 15, 2014	**$ 3,737.52**

nationalgrid

PO Box 960
Northborough MA 01532

ENTER AMOUNT ENCLOSED
$

Write account number on check and make payable to National Grid

********ALL FOR AADC 015
WORCESTER POLYTECHNIC
OFFICE OF FACILITIES
100 INSTITUTE RD
WORCESTER MA 01609

056006

NATIONAL GRID
PO BOX 11737
NEWARK NJ 07101-4737

J.2: NSTAR—East Hall

NSTAR

WPI
OFC OF FACILITIES
100 INSTITUTE RD
WORCHESTER MA 01609-2280

016092280002

NSTAR Gas

This Detail Bill Is for Your Records Only. Do Not Use this Stub for Payment.

East

Account Number	Billing Date	Next Read Date
	Jan 17, 2014	Feb 14, 2014

Service Provided to

WPI
30 BOYNTON ST DORM
WORCESTER MA 01609

Account Summary

Previous Bill	3,318.66
Payments - Thank You	-3,318.66
Delivery Charges Total	2,069.01
Delivery Chgs Balance	**$2,069.01**

Gas Used

Rate 27-Commercial Heating
Meter X000616

Jan 15, 2014 Actual Read		34540
Dec 18, 2013 Actual Read	-	28752
CCF Used in 28 Days		5788
Times Therm Factor	X	1.0296
Therms Billed this Meter		5959

Date	Therms
01/15	5959
12/18	6566
11/15	3171
10/16	1346
09/17	781
08/15	306
07/18	411
06/14	795
05/16	1713
04/16	4271
03/15	5038
02/14	6872
01/16	5967

Charges for Gas Used

Delivery Charges (PRORATED)

Customer Charge		30.00
Distribution	.22910 X 5959 Therms	1,365.21
Distrib Adj	.11307 X 5959 Therms	673.80
Delivery Charges Total		**2,069.01**

CHARGES ARE SUBJECT TO 0.81% INTEREST AFTER 25 DAYS.

NSTAR

J.3: National Grid—Founders Hall

Founders

nationalgrid

SERVICE FOR
WPI
26 BOYNTON ST POLE MH338
WORCESTER MA 01609

BILLING PERIOD
Dec 16, 2013 to Jan 17, 2014

ACCOUNT NUMBER

PLEASE PAY BY
Feb 15, 2014

PAGE 1 of 2

AMOUNT DUE
$ 2,752.68

www.nationalgrid.com
CUSTOMER SERVICE
1-800-322-3223
CREDIT DEPARTMENT
1-888-211-1313
POWER OUTAGE OR DOWNED LINE
1-800-465-1212
EMAIL BILLING INQUIRES
customerservice@us.ngrid.com
CORRESPONDENCE ADDRESS
PO Box 960
Northborough, MA 01532-0960
ELECTRIC PAYMENT ADDRESS
PO Box 11737
Newark, NJ 07101-4737
DATE BILL ISSUED
Jan 22, 2014

Enrollment Information

To enroll with a supplier or change to another supplier, you will need the following information about your account:
Loadzone WCMA
Acct No: 27628-90015 Cycle: 14, WPI

Electric Usage History

Month	kWh	Month	kWh
Jan 13	52800	Aug 13	47680
Feb 13	80320	Sep 13	70080
Mar 13	63840	Oct 13	69920
Apr 13	67040	Nov 13	66080
May 13	49280	Dec 13	70880
Jun 13	32960	Jan 14	51040
Jul 13	40480		

Billed Demand Last 12 months

Minimum	86.4
Maximum	201.6
Average	156.2

ACCOUNT BALANCE

Previous Balance		3,411.08
Payment Received on JAN 13 (ACH)	*THANK YOU*	- 3,411.08
Current Charges		+ 2,752.68
	Amount Due ▶	**$ 2,752.68**

To avoid late payment charges of 0.82%, $ 2,752.68 must be received by Feb 15 2014.

➤ **GO PAPERLESS:** You'll help yourself and the environment by signing up to manage your bills online at www.nationalgridus.com/gopaperless.

DETAIL OF CURRENT CHARGES

Delivery Services

Type of Service	Current Reading	-	Previous Reading	=	Difference	x	Meter Multiplier	=	Total Usage
Energy	31955 *Actual*		31636 *Actual*		319		160		51040 kWh
							Total Energy		**51040 kWh**

Demand-kW 169.6 kW
Demand-kVA 172.8 kVA

Billed Demand **169.6 kW**

METER NUMBER 05800149 NEXT SCHEDULED READ DATE Feb 19
SERVICE PERIOD Dec 16 - Jan 17 NUMBER OF DAYS IN PERIOD 32
RATE General Service - Demand G-2 VOLTAGE DELIVERY LEVEL 0 - 2.2 kv

Customer Charge		16.56
Distribution Charge	0.0086 x 51040 kWh	438.94
Transition Charge	0.00158 x 51040 kWh	80.64
Transmission Charge	0.01736 x 51040 kWh	886.06
Distribution Demand Chg	6 x 169.6 kW	1,017.60
Energy Efficiency Chg	0.00563 x 51040 kWh	287.36
Renewable Energy Chg	0.0005 x 51040 kWh	25.52
	Total Delivery Services	**$ 2,752.68**

KEEP THIS PORTION FOR YOUR RECORDS.

RETURN THIS PORTION WITH YOUR PAYMENT.

nationalgrid

PO Box 960
Northborough MA 01532

ACCOUNT NUMBER	PLEASE PAY BY	AMOUNT DUE
	Feb 15, 2014	**$ 2,752.68**

ENTER AMOUNT ENCLOSED
$

Write account number on check and make payable to National Grid

********ALL FOR AADC 015
WPI
OFFICE OF FACILITIES
100 INSTITUTE RD
WORCESTER MA 01609

055813

NATIONAL GRID
PO BOX 11737
NEWARK NJ 07101-4737

J.4: NSTAR—Founders Hall

NSTAR

WPI
OFC OF FACILITIES
100 INSTITUTE RD
WORCHESTER MA 01609-2280
016092280002

NSTAR Gas

This Detail Bill Is for Your Records Only. Do Not Use this Stub for Payment.

Founders
Main

Account Number	Billing Date	Next Read Date
	Jan 22, 2014	Feb 14, 2014

Service Provided to

WPI
69 INSTITUTE RD FOUNDERS
WORCESTER MA 01609

Account Summary

Previous Bill	2,315.75
Payment - Thank You	-2,315.75
Delivery Charges Total	2,708.81
Delivery Chgs Balance	**$2,708.81**

Gas Used

Rate 27-Commercial Heating
Meter 0051202

Jan 16, 2014 Estimated Read		786369
Dec 16, 2013 Estimated Read	-	778772
CCF Used in 31 Days		7597
Times Therm Factor	X	1.0295
Therms Billed this Meter		7821

Date	Therms
01/16*	7821
12/16*	6501
11/15	3937
10/16*	738
09/17	418
07/18	1955
04/16	5330
03/15	5572
02/14	7362
01/16	6106

*Estimate

Charges for Gas Used

Delivery Charges (PRORATED)

Customer Charge		30.00
Distribution	.22910 X 7821 Therms	1,791.79
Distrib Adj	.11341 X 7821 Therms	887.02
Delivery Charges Total		**2,708.81**

CHARGES ARE SUBJECT TO 0.81% INTEREST AFTER 25 DAYS.

NSTAR

J.5: 2013 Cost History

2013 Electric Usage History (kWh)

Month	East	Founders	East ($)	Founders ($)
January	79400	52800	10311.69	6857.142857
February	100200	80320	13012.99	10431.16883
March	86200	63840	11194.81	8290.909091
April	86000	67040	11168.83	8706.493506
May	89200	49280	11584.42	6400
June	90800	32960	11792.21	4280.519481
July	116600	40480	15142.86	5257.142857
August	112000	47680	14545.45	6192.207792
September	107400	70080	13948.05	9101.298701
October	99800	69920	12961.04	9080.519481
November	87800	66080	11402.6	8581.818182
December	96200	70880	12493.51	9205.194805
January 14'	83800	51040	10883.12	6628.571429

2013 Gas Usage History (kWh)

Month	East	Founders	East ($)	Founders ($)
January	5967	6106	4815.534	4927.012
February	6872	7362	5541.344	5934.324
March	5038	5572	4070.476	4498.744
April	4271	5330	3455.342	4304.66
May	1713		1403.826	
June	795		667.59	
July	411	1955	359.622	1597.91
August	306		275.412	
September	781	418	656.362	365.236
October	1346	738	1109.492	621.876
November	3171	3937	2573.142	3187.474
December	6566	6501	5295.932	5243.802
January 14	5959	7821	4809.118	6302.442