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Development of a Methodology for Dormitory Energy Load Estimation and Analysis

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This dissertation is dedicated to my grandfather, Dr. Lorin Krusberg.

Thanks for everything Granddad.

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Abstract

In recent years interest in reducing energy consumption at the building levels has been increasing, especially in the higher education sector. Many examples exist of higher education institutions reducing their environmental impact through energy consumption reductions, however the majority of these are anecdotal examples and it is difficult to replicate these initiatives at other institutions, either due to resource constraints, financial constraints, or a lack of reproducible methodology. This issue is further compounded by the fact that a generalized methodology does not exist for the purposes of estimating building energy loads, especially in dormitories in the absence of expensive and sophisticated metering and sub-metering systems. A study was completed in which a generalized methodology was developed for the purposes of estimating dormitory energy loads and used to analyze the energy consumption of four representative residence halls on James Madison University campus. The purpose is to describe energy consumption using only building level metered data recorded every month as starting point for the determination of the most beneficial energy saving options for a university to focus their efforts on reducing total energy consumption. Total energy usage profiles over time, energy usage indexes, and total dormitory energy load profiles by end use contribution of total energy consumption analyses were generated and show that on the JMU campus, the vast majority of energy consumption, 69-76%, is as a result of providing heating and domestic hot water to the residence halls. The resulting 24-31% of energy consumption is as a result of electricity consumption in the residence halls. The results indicate that the most popular areas for reduction of energy consumption, namely lighting and plug loads, are not the most beneficial areas, but rather initiatives directed at reducing heating and domestic how water loads may provide the greatest reductions in energy consumption.

Chapter One: Introduction[1]

Research Question

In the past few years in the United States, higher education institutions across the nation have made pledges and real commitments to making their campuses more sustainable. Some of these institutions have made real, significant reductions in energy use, carbon emissions reductions, green building improvements, renewable energy use, and many other facets of sustainability as reported online by Powers (Powers, 2007). (Klein, Colleges & Universities Report Significant Progress in Confronting Climate Disruption, 2011) One of the easiest ways to make significant strides towards sustainability is through the “low-hanging fruit”, as Dr. Chu puts it, of energy efficiency and conservations efforts that are generally no-cost or low-cost options. However, many universities have yet to make significant efforts towards these goals. (Klein, Inactive Institutions Removed from American College & University Presidents’ Climate Commitment, 2011) This is due mainly to a lack of generalized guidelines on how an institution goes about assessing campus energy use and implementing the measures to obtain these no- or low-cost options. In order to initiate any program for increasing energy efficiency or conservation, whether it is low-cost or a capital intensive project, it is essential that an institution has a clear picture of where they stand on energy use so that energy savings as a result of any project or program can be estimated. A methodology for the estimation of energy loads is needed to provide the basis for this first step.

The promotion of sustainable practices in more higher education institutions across the nation requires a generalized methodology for estimating building energy loads in university residence halls in the absence of sophisticated metering, sub-metering, and detailed

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[1] This research was funded as part of a grant from the US Environmental Protection Agency, "Reducing Greenhouse Gases Through Low Cost Energy Management," Award Number XA-83420401-0.

instrumentation of energy use patterns must be created. The methodology will need to aid higher education institutions in determining the baseline energy use of their residence halls in order to monitor the real savings of any energy efficiency and conservation efforts. It will have to provide an outline on how a university determines energy use patterns with only building level metering of electricity, natural gas, steam, or any other energy source used in the provision of heating and cooling, lighting, hot water, and student energy use. The methodology will have to be general enough for a university to apply these techniques in the presence of a variety of building types, energy sources, and uses within a single university and be applied to other universities that may have an entirely different building stock with an entirely different set of building parameters. A methodology that fits these requirements is a critical element to achieving a greater percentage of universities across the nation make headway into reducing energy use and increasing sustainability.

Significance

United States higher education institutions play a critical role in shaping the future of society and determining the pace of progress toward sustainability and overcoming the serious environmental issues the nation now faces. Higher education is in a unique position to lead the way for a sustainable future and indeed in the past few years there has been major pushes by universities across the nation to become more sustainable. However, Dr. Anthony Cortese (Cortese, Integrating Sustainability in the Learning Community, 2005) notes in his article *Integrating Sustainability in the Learning Community* that “It is not the ability of higher education to take on this challenge. It is the will and the timeframe to do so.” Higher education institutions are training tomorrow’s leaders, have the resources at their disposal to be community leaders in sustainability, and energy efficiency improvements in building infrastructure and best practices energy management has the potential to provide key gains towards sustainability.

The over 4000 higher education institutions in the United States represent over $2 billion in annual energy expenditures. (Papadakis, 2009) Energy consumption in higher education is especially building intensive and energy management of these buildings should be an important part of standard operations and management procedures. Traditionally, the goal of energy management has been to maximize profits or to minimize costs, occasionally combined with sub-objectives such as improving energy efficiency and reducing energy use, cultivating good communications on energy matters, or finding new and better ways to increase returns from energy investments. (Capehart, Turner, & Kennedy, Guide to Energy Management 4th Ed., 2003) As environmental concerns begin to become more and more a part of the public consciousness, energy management has taken on additional objectives; the reduction of greenhouse gases, prevention of acid-rain events, reduction of ozone layer depletion, and a multitude of other environmental side effects arising from the use of fossil fuel based energy. (Eastop & Croft, 1995)

The significance of the sustainability movement in higher education cannot be overlooked. Higher education provides the foundation on which tomorrow’s leaders will be basing their decisions. By making sustainability an integral part of the education experience and practicing sustainability in every part of the higher education operations, working in close cooperation with local and regional communities to promote sustainability, and building those sustainability decisions on no-cost or low-cost energy management practices, major headway can be made toward making the changes that so many experts are adamant need to happen in the next ten to twenty years. However, to make more substantial headway into sustainability, most if not all colleges and universities in the US will need to make serious commitments towards reducing their environmental footprints. Progress will have to be made in addressing the issues that prevent all higher education institutions from making these commitments.

An aggressive energy management program can usually result in energy cost savings of 5-15 percent with little to no capital required. (Capehart, Turner, & Kennedy, Guide to Energy Management 4th Ed., 2003) While energy cost savings have traditionally been the goal of energy management, they are accompanied by greenhouse gas emission savings, pollution savings, and a reduced overall consumption of the fuel used to generate the energy. A higher education institution can expect to see substantial savings in greenhouse gas emissions through aggressive energy management and the ability to obtain substantial savings with no-lost or low-cost measures makes energy management the first area that any institution looking to make gains towards sustainability should look into.

There are several issues that prevent many higher education institutions from making progress on energy efficiency and conservation that other sectors have made. Despite the potential that higher education has regarding progressing the sustainability movement, there are several barriers that exist to conservation and energy efficiency in higher education. Three barriers that prevent higher education from making more widespread progress into sustainability are a lack of readily accessible clear guidance on how to implement no- or low-cost initiatives, the cost prohibitive nature of major retrofits and upgrades to infrastructure, and the variation not only between university's plant, equipment, and facilities, but these variations within the universities themselves.

Readily accessible, reproducible, clear guidance on how to implement no- or low-cost initiatives is either unavailable or lacking for higher education institutions. The major higher education sustainability groups and programs such as EPA's Energy Star for Higher Education Program, Alliance to Save Energy Green Campus Program, Association for the Advancement of Sustainability in Higher Education and a multitude of others praise the success stories of individual campus efforts such as Carleton College's installation of wind turbines to supply 100% of their electricity needs or Harvard University's Green Campus Loan Fund of $12 million, but these reflect unique campus situations. (Papadakis, 2009) Carleton College happens to have a student population of only 2000 and is located in Minnesota which has abundant wind resources and very favorable wind power financing. (Papadakis, 2009) Harvard University's Green Campus Fund reflects an economic resource at the university that many, if not most, higher education institutions do not have. (Papadakis, 2009)

Many examples and success stories of sustainability at campuses around the country grace the media each year, but many are simply anecdotal and that methodology, if it can even be obtained, cannot be generalized to be used at other universities across the nation.[2] Even resources available to help higher education in these efforts such as EPA's Energy Star for Higher Education Program Energy Management Guidelines are vague at best, offering advice such as "Appoint an Energy Director", or "Gather and Track Data" that provide several bullets about how a university should go about these efforts, but with very little detail on the process of these steps. Not only is there a lack of clear guidelines supported by anecdotal evidence, but many of the successful efforts undertaken by higher education institutions constitute major renovations, upgrades, or installation of equipment that are cost prohibitive to other institutions.

Major retrofits, renovations, upgrades, or addition of equipment can be cost prohibitive. Despite the collective operating budget of $280 billion of the 4,100 higher education institutions in the United States these funds are not distributed equally. (Cortese, The Critical Role of Higher Education in Creating a Sustainable Future, 2003) The high capital costs of major renovations, retrofits, and upgrades are simply too cost prohibitive for most of the universities in the nation. The university and college capital budgeting process may not consider the long term operational savings and these processes often operate on such a long approval and construction timeline that

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[2] Examples of this anecdotal evidence include press releases concerning universities mentioned above such as Carlton College's installation of wind turbines providing 100% of their electricity and Harvard University's Green Campus Loan Fund of $12 million. Another recent example is the Association for the Advancement of Sustainability in Higher Education's (AASHE) database of campus solar installations which provides information on the year completed and capacity installed, many of which required capital investments in the hundreds of thousands if not millions of dollars range. (AASHE, 2011) A fourth example is the Energy Efficiency Award press release on the Energy Star® for Higher Education website that lauds the University of Michigan for their commitment toward energy management with a claim that the university will save $9.7 million annually in energy costs, but offers little additional information for interested institutions looking to do the same. (Brown, 2004)

any savings will be deferred well into the future. (Papadakis, 2009) The two commonly recommended financing alternatives for these sorts of projects, tax exempt lease purchase agreements and energy service performance contracts or ESCO's have problems of their own. First of all these financing options often have minimum thresholds of $1-2 million and the legal status and terms of the agreements vary from state to state. (Papadakis, 2009) Additionally the ESCO industry is full of bad contractors and both options require a degree of financial knowledge in order to negotiate agreements with good contractors. (Papadakis, 2009) Not only is there the issue of the cost prohibitive nature of major renovations and upgrades, but the buildings, equipment, and facilities between universities, and even within universities can vary significantly.

The nature of higher education institutions as places of learning and research for a variety of disciplines across the nation with their own specific student populations, needs, goals, building stocks, and budgets lends itself to a complex plant, equipment, and facilities mix between any two universities and within the universities themselves. The sheer number of energy saving measures that can be implemented in higher education can be overwhelming due to this diverse mix of facilities, infrastructure, and stakeholders on a college campus. All of the different buildings on campuses, from residence halls to dining halls, laboratories, offices, power plants, and any other building type that may be located on a campus each have their own distinct energy use patterns and equipment configurations. Finding information on the best practices of energy management in each of these building types is time consuming and many times the best practices for one type of building do not lend themselves to implementation in other building types. One example is the common suggestion to "set back thermostats at night" which is well suited for spaces that have individual controls, but holds no relevance for buildings with automated set point temperature programming.

These barriers illustrate the needs for a clear set of procedures and guidelines for higher education to achieve environmental gains using no- and low-cost options. A generalized methodology for energy management, especially baseline estimation of end use energy consumption, is crucial to this effort in order to allow universities and colleges to measure the gains made from these “low hanging fruit” options. This will help to overcome the anecdotal evidence issues that plague efforts currently, could possibly result in savings comparable to major retrofits and upgrades without the high capital costs, and counteract the issues of variation between universities and within universities.

Project Scope

The scope of this project is to develop residence hall energy load profiles and end use energy estimations using readily available data in the absence of a sophisticated metering, sub-metering, and detailed energy use instrumentation. The goal for this project is to be able to use these load profiles and end use estimations to develop a generalized methodology that can be adopted by other universities wishing to identify low and no-cost options for energy efficiency and conservation. The expectation is that with this methodology, universities will be able to make the first step toward greater energy sustainability, which is simply accounting for current energy usages in order to identify the areas that can benefit the most from an efficiency or conservation initiative and is the starting point of any energy management program.

Energy management means different things to different people; Capeheart, Turner, and Kennedy (Capehart, Turner, & Kennedy, Guide to Energy Management 5th Ed., 2006) describe energy management as “the judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions.” This has been the primary focus of energy management since its inception during the 1973 energy embargo and in the years since, energy management began to focus more and more on projects as a means to conserve energy. (Piper, 1999) Only in recent years has there been a move back to the “low-hanging fruit” of energy efficiency and conservation including the role operations and maintenance can play in lowering energy consumption. Energy management will be looked at in more detail in Chapter 2 of this dissertation.

This project will focus on four residence hall on the James Madison University campus representing different mixes of energy sources, equipment, age of building, and building configuration on the JMU campus that we believe represent the majority of residence halls across the United States. Using only building level metered data, load profiles and end use breakdowns of energy use will be developed that represent a mix of electricity, steam, and natural gas energy use. By focusing our efforts on these buildings, and the common methodology between them, the intention is to provide a solid, detailed, but ultimately generalized methodology that any university can adopt no matter the mix of buildings stock available to them.

Overview of Thesis

The dissertation is broken down into four main sections; a literature review, methodology, data analysis, and conclusion. The literature review contains the significance of load profiling and energy management; including what each of these is in detail, what can be learned from them, and why they are important for energy savings. It also contains the ideal load profiling conditions, including data acquisition systems, what data is measured and how, current technology including dashboards and realtime data analysis and strategic energy analysis, benefits of these systems, and how they are different than building automation systems. Finally this section contains the constraints of this project and the JMU building profiles for the four buildings of interest.

The methodology section contains the generalized methodology for developing residence hall load profiles and end use energy breakdowns. This section contains a step-by-step methodology for the collection of pertinent energy data, non-weather dependent energy usage estimation, weather adjustment of energy data, and creation of load profiles. Additionally, end use breakdowns including estimation of percentage of energy usage by process, e.g. lighting, plug loads, and process loads, for identification of the areas of energy use most in need of energy efficiency and conservation measures that will provide the greatest benefit to reduction goals is included in this section.

The data analysis part of this paper includes the results of the analysis of the four representative residence halls. This section includes the original data for each dorm, the non-weather dependent estimations, the weather adjusted energy usage data, the load profiles developed from these data, and the energy usage breakdown estimations by end use. This section also contains the EUI, or energy usage indexes for these four buildings, including energy use per resident and per square footage of building area.

The conclusion section contains the insights and trends observed in development of these profiles, issues, barriers, and constraints encountered in the process of completing this project, and the areas for improvement and further study.

Chapter 2: Literature Review

Significance of Energy Management and Load Profiling

Energy management is a term that is becoming more and more prevalent in the public consciousness as the perception that fossil fuels really are a limited resource and that the consumption of these fuels is having a severe negative impact on global ecosystems through climate change and direct pollution. Energy management has differing meanings to different people, depending on their background, exposure, and goals for the management of energy. In *Guide to Energy Management 5th Edition*, the authors (Capehart et al., 2006) describe energy management as "the judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions." (Capehart, Turner, & Kennedy, Guide to Energy Management 5th Ed., 2006) They go on to state that this primary objective of energy management can be accompanied by "desirable sub-objectives", such as improving energy efficiency and reducing energy use, thereby reducing costs, cultivating good communications on energy matters, and a variety of others. (Capehart, Turner, & Kennedy, Guide to Energy Management 5th Ed., 2006) Eastop and Croft state that "the overall objectives of the Energy Manager are to save money." (Eastop & Croft, 1995) Piper claims that "[Energy Management's] objective is to see that all energy using systems within the organization are supplied with all of the energy that they need, when they need it, in the form that they need it, at the lowest possible cost, and that the energy supplied to those systems is used as efficiently as possible." (Piper, 1999) The basic premise of energy management put forth by these authors is the same, and Eastop and Croft put it most succinctly when they say that the objectives are to save money. These statements represent the traditional view on energy management, that energy is a resource that needs to be managed as any other resource would be with the goal of reducing costs in order to maximize profits. However this view is changing, Blok (Blok, 2007) states that while reducing energy costs will usually be the predominant reason, “other reasons may include the wish to produce in a more environmentally friendly way, the desire to improve the corporate image, or obligations imposed by the government” and Turner states that in addition to continuing to be competitive in the global marketplace, energy management can aid corporations in “meeting more stringent environmental quality standards, primarily relating to global warming and reducing acid rain.” (Blok, 2007) (Turner, 2007) It is through these “subobjectives” that energy management may be most easily transferred from the realm of industry and profit maximization to other sectors such as higher education, where profit is not the goal, but greater environmental sustainability, reduction in environmental footprint, and reduction of energy use to curtail rising operational costs may be the primary objectives.

Whatever the goals for an energy management program, the process will remain relatively unchanged. “Energy management is the permanent and systematic management of the production, conversion, and use of energy within an organization” and in general is a cyclical process. (Blok, 2007) Blok describes the process of energy management in four main steps;

1. Monitoring of energy production, conversion and use;
2. Reporting and analysis, including indicators of energy use and energy efficiency, and re-analysis of improvement options;
3. Preparation and planning of adaptations in the energy system (adaptations may include organizational changes, investments in energy conservation, adaptations to the production process, campaigns aimed at changing behavior); and
4. Implementation of the adaptations. (Blok, 2007)

The main objective of this project concerns the first two steps of this process, monitoring of energy production, conversion, and use and reporting and analysis of energy usage, primarily the creation of load profiles of building energy usage that form the basis for the analysis of improvement options and the implementation of these improvements in order to reduce energy usage, improve environmentally sustainability, and reduce the environmental footprint of higher education institutions.

A load profile for a building provides the basis for a load analysis, which in turn, is the basis of the analysis of improvement options and the implementation of those changes. A load profile is, most simply, a graphical representation of historical energy usage data over a set time frame. (Turner, 2007) The time frame can vary depending on the availability of historical data and the detail of monitoring; there can be a daily load profile which displays the energy usage over a twenty-four hour timeframe, the energy usage over a particular month, or the annual energy usage load profile which displays the energy usage as a function of month of the year. (Turner, 2007) From a graphical representation of the energy use data it is possible to review the data for seasonal patterns of use and peak demands for the determination of what demands or usages can be eliminated or reduced through energy efficiency and conservation measures. (Turner, 2007) Energy load profiles can be generated for a specific energy source or for a combination of energy sources, depending again, on the availability of the data. A recent popular maxim is that “if you don’t collect it – you can’t measure it, and if you don’t measure it – you can’t manage it”, and this describes the most important purpose for the generation of load profiles, to provide the ground level snapshot of current energy usage in order to identify the areas that are most in need of, and can benefit the most from, energy efficiency and conservation initiatives.

Ideal Load Profile Conditions

The more detailed the data on energy usages within an organization is, the more accurate the load analysis of that data can be and the more specific energy efficiency and conservation measures can be. An ideal load profile will contain data from individual subsystems within a buildings so that individual processes, circuits, or even equipment that is not performing at a desirable levels can be identified and improvements can be made where they are most needed with a high degree of certainty that the desired reductions in energy usage will be obtained. The most critical part of an ideal load profile is the high level of detailed energy data being readily available. In recent years, several data acquisition systems, advanced metering systems, real-time data analysis and strategic analysis software packages have come onto the market to aid in the management of energy in buildings and that can readily generate load profiles and provide real-time or near real-time load analysis to quickly identify problem areas.

Data acquisition systems or advanced metering systems (AMSs) are systems that go far beyond the traditional campus or individual building level meters installed by utilities. An advanced metering system collects electrical consumption data, real-time phase diagnostics, as well as natural gas, steam, potable water, BTUs, and any other data desired through sub-metering of individual processes, circuits, or even down to the equipment level. (Stein, 2011) AMSs have the capability (depending on the sophistication of the system) of collecting data at very minute intervals, most commonly at 15-minute intervals and displaying that data in real-time or near-real time with complete load analysis if coupled with a dashboard system.

A dashboard system accesses the data collected by an AMS in order to provide consumption analysis for the building as a whole or any number of building subsystems, depending on the level at which sub-metering is being conducted. A dashboard has the ability to display the energy usage analysis for any system that is sub-metered in a building; heating, ventilation and air-conditioning (HVAC) systems, lighting, elevators, and process power. A well designed dashboard can display these individual loads over time, the costs associated with them, as well as the total building usages and costs. Additionally, it can have the capability to provide a percentage breakdown of energy usages by system or subsystem in a building. Dashboards can be web-based or provided as a program on a computer that is the designated destination for data collected by the AMS. A dashboard system requires an advanced metering system in order to be useful to an organization, but once available, can provide invaluable insight into an organization's energy consumption to provide the basis for real-time data analysis and strategic analysis of that consumption.

The benefits of advanced metering systems coupled with dashboard systems are multi-faceted. Data gathered from daily, weekly, and monthly energy consumption profiles can aid in the identification of many areas of possible savings. (Stein, 2011) It can identify equipment left on during non-working hours, identify energy usages that can be shifted to non-peak periods and most importantly allow for measurement and verification of energy usage and the effectiveness of associated efficiency and conservation measures. (Stein, 2011) Energy efficiency investments based solely on engineering estimates are often incorrect and sub-meters positioned properly can provide an accurate measurement of savings. (Stein, 2011)

It is critical to point out that while AMS and dashboard systems can be integrated with Building Automation Systems (BAS), they are not the same thing. Building Automation Systems provide users with the ability to remotely control the processes within a building, whether they are lighting, refrigeration, elevators, process power, HVAC, or fire suppression systems. (Johnson Controls , 2011) BAS has the ability to turn these systems on and off remotely, monitor their operations, maintain set temperatures and humidity levels, and alert the owners of the buildings of any anomalies in system operations. (Johnson Controls , 2011) Their primary function is not, however, the collection and analysis of building energy usage and analysis of those usages and AMS/dashboard systems need to be installed or integrated with BAS to provide this information. (Johnson Controls , 2011)

Under Constraint

This project is not operating under ideal load profiling conditions, and while several of the residence halls on the James Madison University campus do have building automation systems, none of the buildings are equipped with advanced metering systems or sophisticated sub-metering of any kind. This is a similar situation shared with many universities across the nation. JMU residence halls only have building level meters for electricity and either steam or natural gas, depending upon the building. This data is collected at the end of every month and data is currently available for the 2005-2006 fiscal year[3] through the 2009-2010 fiscal year for all but two of the dorms.

The original plan for this project was to develop load profiles for four residence halls representing drastically different floor plans, living area, occupants, and energy sources, develop a generalized methodology based on the generation of these profiles, and then install a series of sub-meters in order to validate the load profiles. A company from Columbia, MD, Spatial Systems Associates®, was preparing to install an advanced metering system and dashboard system on one or more of the residence halls to aid us in the validation of the load profiles and thought was given to installing our own meters and data-logging equipment on one of the dorms to provide a comparison between the three methodologies in terms of accuracy and effort involved. However, due to unforeseen complications resulting in a contraction of the JMU Facilities Management workforce, we are unable to install either a commercial system or our own sub-meters.

As a result, all results and conclusions are based solely upon the analysis of the monthly collected data from the building level meters. This fits more in line with the original scope of the project, which was to provide a methodology to generate these load profiles under fiscal and labor

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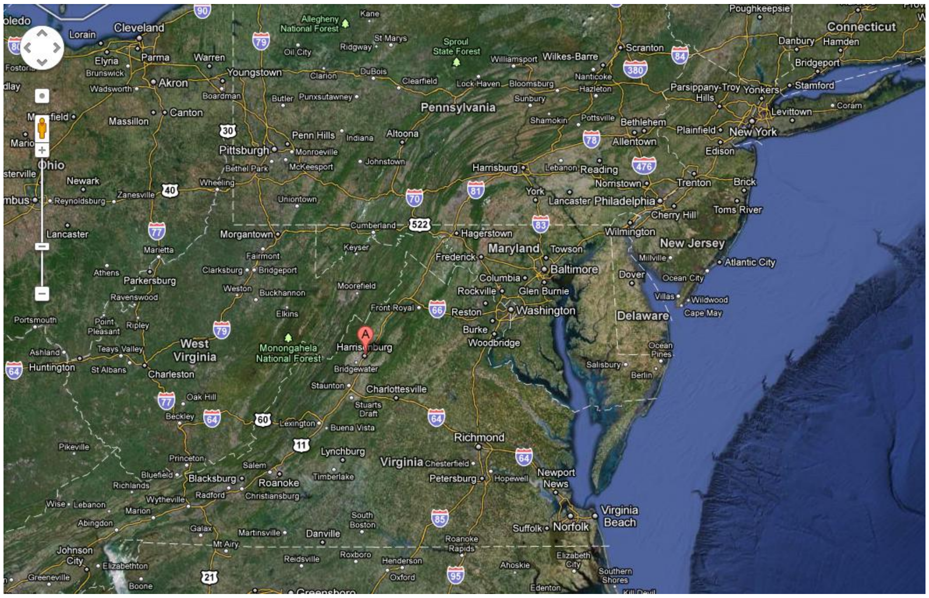
[3] Note that fiscal year in the JMU accounting system refers to July 1st through June 30th.

constraints that may be present at other universities that are looking to initiate energy efficiency and conservation programs. All analysis has been completed using readily available data and software.

James Madison University Project Locale

James Madison University is a master's level institution located in Harrisonburg, Virginia in the Shenandoah Valley, approximately 130 miles southwest of Washington, D.C. and 130 miles west by northwest of Richmond, VA, the capital of the Commonwealth of Virginia. James Madison University was established in 1908 as *The State Normal and Industrial School for Women* and in 1914, the name was changed to *The State Normal School for Women at Harrisonburg.* The school initially offered today's equivalents of technical training and junior college courses. In 1916, authorization to award bachelor's degrees was granted to the school. The school became the *State Teachers College at Harrisonburg* in 1924 and *Madison College* in 1938. It did not become *James Madison University* until 1976.



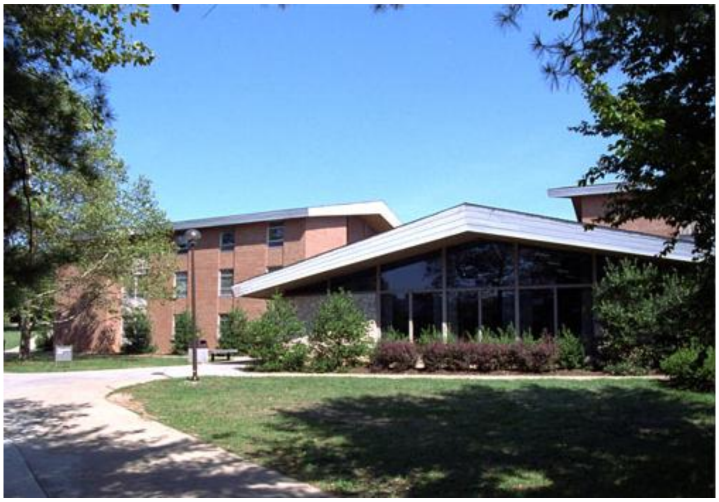
James Madison University is located in Harrisonburg in the Shenandoah Valley area of the Commonwealth of Virginia. http://maps.google.com

James Madison University has a full time student population of over 17,000 and houses 6,000 students on campus. All freshmen, approximately 4,000 students, are required to live on campus with the remaining 2,000 occupants being upperclassmen. There is no graduate housing on campus and the vast majority of the residence halls are freshmen only. There is a single residence hall that is designated as substance free (no alcohol or cigarettes). All sororities are located in a cluster of residence halls identical to those housing non-Greek students. Dormitories are used almost exclusively for residential purposes, with no dining services or computer labs in any of the residence halls and only two housing small administrative offices.

There are 33 residence halls on JMU's campus that are separated into six main areas; Bluestone Halls area, Hillside Halls area, Lake Halls area, Skyline Halls area, the Treehouses area, and the Village. These halls represent 1.4 million ft^2 of air conditioned space (about 30% of the university total) and 16% of total energy costs. The building stock ranges in age from 2 to 100 years old (as of 2011) with 50% of the total square footage being 35-50 years old. All residence halls are metered or sub-metered for electricity and natural gas and all but three buildings on the campus steam loop are sub-metered with no residence halls using fuel oil or propane. The buildings represent common types of energy systems in residence facilities, including:

- District heating systems and in-house boilers
- Facilities with and without air conditioning
- Steam chillers and conventional cooling systems
- Fully integrated building controls and individual room controls
- Small to large square footage range (13,000 – 105,000 ft^2)
- Various vintages of HVAC equipment
- A spectrum of building retrofits and upgrades installed in the past decade

There are four dorms of interest for this project; Chappelear, Potomac, Eagle, and Converse. Chappelear Hall is in the Village area of campus and was completed in 1968. It has an area of 47,054 ft^2 with 103 rooms and 204 beds. It is not air conditioned and uses natural gas for heating and hot water.



Chappelear Hall in the Village Area of the JMU Campus.
http://www.jmu.edu/map/buildings/CHAP.shtml

Potomac Hall is located in the Skyline area of campus and was completed in 1998. It has an area of 105,052 ft^2 with 215 rooms and 414 beds. It is air conditioned with steam provided from the waste to steam plant for heating and hot water.

Potomac Hall in the Skyline Area of the JMU Campus.
http://www.jmu.edu/map/buildings/PMAC.shtml

Eagle is located in the Lake Side area of campus and was completed in 1970. It has an area of 81,785 ft^2 with 240 rooms and 448 beds. It is not air conditioned and uses natural gas for heating and hot water.

Eagle Hall in the Lake Side area of the JMU Campus.
http://www.jmu.edu/map/buildings/EAGL.shtml

Converse Hall is located in the Bluestone area of campus and was completed in 1935. It has an area of 35,602 ft^2 with 58 rooms and 111 beds. It is air conditioned, but the energy source for the air-conditioning is currently being looked into at this time, and the residence hall uses steam for heat and hot water.

Converse Hall in the Bluestone area of the JMU Campus.
http://www.jmu.edu/map/buildings/CONV.shtml

Chapter 3: Methodology

Overview of Chapter

Chapter three of this project is the methodology for estimating building loads based on monthly building meter readings and equipment inventories. It is through this methodology that the analysis of energy data for the four JMU residence halls will be completed. The primary steps discussed here for estimating building loads are:

1. **Data Collection**. Data collection is compiling available energy consumption data into a readily accessible and easily manipulated format for the further analysis of the data.
2. **Non-Weather Dependent Weather Data Estimation.** Non-Weather Dependent Data Estimation is the process of estimating the lowest amount of energy any given building will use at any given time and allow for the removal of non-weather dependent data for the weather normalization process.
3. **Weather Normalization of Weather Dependent Data**. Weather Normalization is the adjustment of weather-dependent energy data for the purposes of fair comparison of energy use data against other buildings or the same building during different years to compensate for differences in weather from year to year.
4. **Generation of Load Profiles for the Buildings**. The load profiles of the buildings are the changes in energy consumption, either of one source of energy or multiple sources of energy, over the course of a set time frame to allow for analysis of those changes in consumption over time.
5. **Estimating Individual Energy Loads Without Direct Load Measurement Data.** Breakdown of energy use is the attempt to assign percentages of total energy consumption to particular end use activities for the purposes of focusing energy saving

options where they will be of the most benefit. The following chapter will elaborate on the process of completing each of these steps in the analysis of building energy data

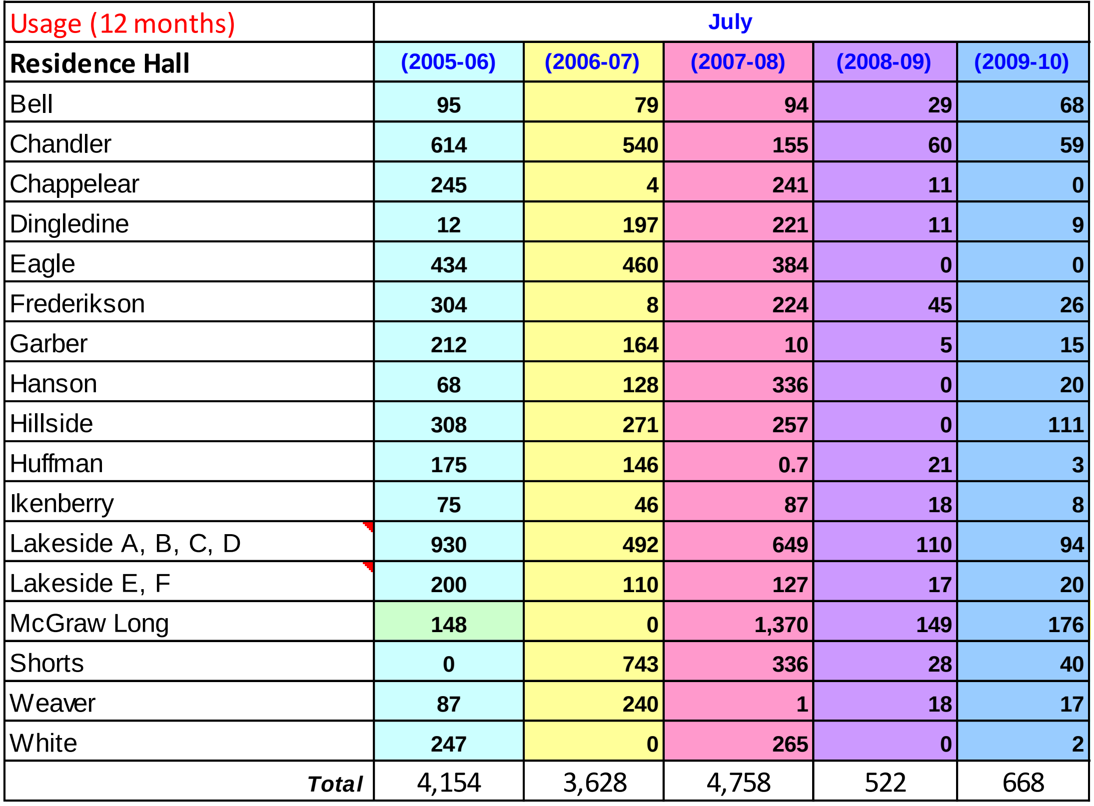
Each of these steps is discussed separately below using illustrative examples from a number of the JMU residence halls. Chapter 4 will apply these methodologies to four specific buildings in order to conduct precise load profiles for energy management.

1. Data Collection

The first step to load profiling buildings is to determine what buildings are to be focused on. The next step is to determine what data is available and at what level of detail it is available. The energy consumption data at JMU was previously compiled as part of a master's dissertation for a student in the ISAT class of 2010. (Bao, 2011)

The dormitories at James Madison University all use electricity and either steam generated from one of two steam plants or natural gas. All of the buildings are metered or submetered at the building level with available monthly data for the fiscal years 2005-2006 through 2009-2010. *Table 3.1* below contains an example of the data for several of the dorms for the month of July for the fiscal years 2005-2006 through 2009-2010 for natural gas. Such data were compiled into Excel® spreadsheets for all buildings, months, and source energy.

Table 3.1: Example of Energy Data Spreadsheet for Natural Gas (Ccf)



Usage (12 months)	July				
Residence Hall	**(2005-06)**	**(2006-07)**	**(2007-08)**	**(2008-09)**	**(2009-10)**
Bell	**95**	**79**	**94**	**29**	**68**
Chandler	**614**	**540**	**155**	**60**	**59**
Chappelear	**245**	**4**	**241**	**11**	**0**
Dingledine	**12**	**197**	**221**	**11**	**9**
Eagle	**434**	**460**	**384**	**0**	**0**
Frederikson	**304**	**8**	**224**	**45**	**26**
Garber	**212**	**164**	**10**	**5**	**15**
Hanson	**68**	**128**	**336**	**0**	**20**
Hillside	**308**	**271**	**257**	**0**	**111**
Huffman	**175**	**146**	**0.7**	**21**	**3**
Ikenberry	**75**	**46**	**87**	**18**	**8**
Lakeside A, B, C, D	**930**	**492**	**649**	**110**	**94**
Lakeside E, F	**200**	**110**	**127**	**17**	**20**
McGraw Long	**148**	**0**	**1,370**	**149**	**176**
Shorts	**0**	**743**	**336**	**28**	**40**
Weaver	**87**	**240**	**1**	**18**	**17**
White	**247**	**0**	**265**	**0**	**2**
Total	4,154	3,628	4,758	522	668

Once this data has been collected, it is crucial to note what energy sources are used by different processes in the dormitories. For JMU, natural gas and steam both provide the energy for building heat and domestic hot water. All other energy loads can be attributed to the electricity use in these residence halls. With such knowledge, it is possible to remove non-weather dependent energy usage from weather-dependent energy consumption.

2. Non-Weather Dependent Energy Use

The next step of the load profiling process is to remove non-weather dependent data from weather-dependent energy usage data. This is done so that trends can be weather normalized to remove year-to-year variations in energy consumption because of weather.

There are two methods by which non-weather dependent usage data can be estimated. The first technique identifies energy sources whose patterns of seasonal energy use are easily separable. For instance, in the JMU residence halls, all buildings use either natural gas or steam for heat and domestic hot water. In these cases it is simply a matter of finding a month in which the building is occupied but the heat is off. At JMU, this is the month of September. Under these conditions, it is reasonable to assume that all energy usage is for domestic hot water. *Figure 3.1* below shows a graph of September natural gas usage for several of the natural gas residence halls for the fiscal year 2005-2006.[4]

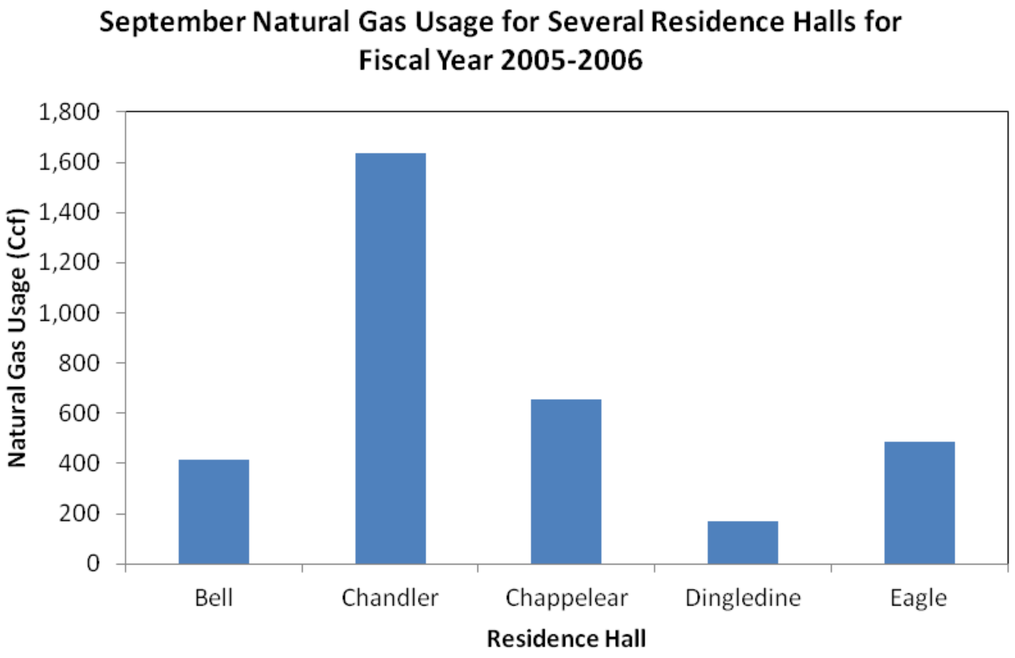


Figure 3.1: Example of September Natural Gas

This method of estimating non-weather dependent usage is only appropriate when usage data is easily separable. If the data are not easily separable, a linear regression non-weather dependent analysis may be more appropriate, as detailed in the Weather Normalization section below. With the non-weather depending energy usage data, it is possible to weather-normalize the data based on climatic conditions.

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[4] These data show that the natural gas consumption in Chandler Hall is much greater than that of the other residence halls in September. This is due to the fact that Chandler Hall contains a dining hall in the first floor so natural gas in this dormitory is used for more than just domestic hot water in this particular case.

3. Weather Normalization of Energy Data

In order to quantify the savings from energy efficiency and conservation measures, it is necessary to compare period-to-period energy consumption. However, in buildings with conditioned space, this comparison is complicated by variation in weather from year to year. In order to compare these periods on a like to like basis, "weather normalization" or "weather correction" must be done to the data.

Weather normalization is used when analyzing the changes in a building's energy consumption. It is often combined with other normalization techniques, such as occupancy and building size normalization (Energy Use Indexing) in order to compare energy consumption across buildings. By weather normalizing energy use, one can determine if changes are the result of weather or other factors. Weather normalization is straight forward; however, it is subject to uncertainties and issues that may have a serious impact on the accuracy of the data, possibly leading to misleading results.

The Weather Normalization Process

Weather correction techniques require the use of degree day data. Degree days are the most commonly used form of historical weather data and are a simplification of outdoor air temperature data.[5] The most readily available degree days data in the United States comes with a base temperature of 65°F. The National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) has data available for many locations around the United States; however, it can be difficult to find current data. This research used data from

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[5] There are two types of degree day data – Heating Degree Days and Cooling Degree Days. Heating degree days, as the name implies, are used for calculations that relate to the heating of buildings, and likewise cooling degree days are used in relation to the cooling of buildings. Heating degree day figures come with a "base temperature" and provide one with a measure of how much (in degrees), and for how long (in days), the outside temperature was below that base temperature. Similarly, cooling degree days provide a measure of how much and for how long the outside temperature was above the base temperature. (Bizzee Software Ltd, 2011)

Degreedays.net, which uses Weather Underground[6] temperature data, to generate daily, weekend, or monthly degree days data for any of a variety of base temperatures for free for up to 36 months of history. The annual heating degree days data was generated using degreedays.net and utilizes temperature data from a weather station in Dayton, Virginia, a location five miles from JMU. The average number of heating degree days per year (1971-2000) for Harrisonburg, VA is 5333 heating degree days, based on NOAA data for Dale Enterprise, VA.

Weather normalization is simply attempting to adjust energy consumption data for climatic variation in order to compare energy consumption between periods. The simplest form of weather normalization is ratio-based normalization. The basic equation for ratio-based weather normalization is:

$$Normalized\ Consumption = \frac{Raw\ Consumption}{Degree\ Days} \times Average\ Degree\ Days$$

Ratio-based weather normalization is a useful way to monitor the performance of buildings from one year to another. By way of example, *Table 3.2* illustrates this calculation performed for two years of annual energy consumption data for Eagle Hall on the JMU campus.

Table 3.2: Normalized Natural Gas Consumption for Eagle Hall.

Year	Natural Gas Consumption (Ccf)	HDD	Ccf/HDD	Average HDD	Normalized Consumption (Ccf)
('07-'08)	33372	4911	6.80	5333	36239
('08-'09)	35466	5358	6.62	5333	35300

The raw consumption values would lead one to believe that 2008-2009 was the more energy efficient year of the two, using more than 2000 less Ccf of natural gas of the 2007-2008 year. The weather normalization shows that this is not the case, with Eagle Hall using 6.62 Ccf/HDD in 2008-2009 as opposed to 6.80 Ccf/HDD 2007-2008, which means that the later year

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[6] Weather Underground is a web-based weather service that incorporates NOAA, NCDC, and personal weather stations that are tied into their network to provide the most localized weather data possible.

was actually the more energy efficient. The normalized consumption reflects this, with 2007-2008 using almost 1000 Ccf more natural gas than 2008-2009.

However, this is a very rough estimation of energy use; in order to provide a more accurate normalized consumption value, it is necessary to separate the weather dependent consumption from the non-weather dependent energy use. The first process of accomplishing this is explained earlier in this chapter under non-weather dependent energy use. In the event that it is not possible to easily separate weather and non-weather dependent portions of the data, a linear regression analysis can be performed to separate the two portions of consumption.

The linear regression analysis method is helpful because in many buildings a single meter exists that measures both weather-dependent and non-weather-dependent consumption as a single value, and the weather-dependent consumption must be isolated from other energy use. This is accomplished through linear regression, whereby degree days are correlated with consumption in order to determine the consumption based on 0 degree days, or consumption that is not associated with space heating and cooling. As an example, *Figure 3.2* illustrates a best-fit line for weather-normalizing natural gas consumption in Eagle Hall. The equation generated is:

$$y = 6.6462x + 61.078$$

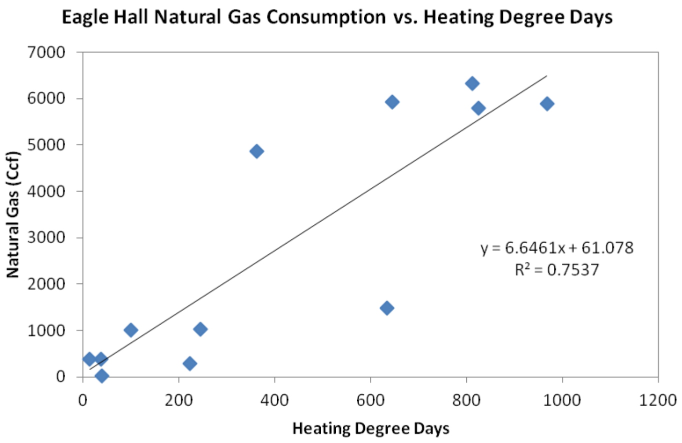

Figure 3.2. Scatter Plot of Natural Gas Consumption vs Heating Degree Days for Eagle Hall.

This equation shows how much natural gas consumption should increase for every increase in the number of heating degree days. For this set of data, monthly natural gas consumption should increase by 6.6461 Ccf for every one increase in degree days. The *y*-intercept of 61.078 tells us that our monthly non-weather dependent natural gas consumption should be 61.078 Ccf. This is the consumption that will be present even when there are zero degree days in a given month. The R^2 value, or correlation coefficient, of 0.7537 indicates that this equation accounts for approximately 75 percent of the variation in the data. The closer the correlation coefficient is to 1, the more accurate the equation is at predicting increases in consumption based on increases in heating degree days.

With the estimate of non-weather dependent consumption, a more accurate weather normalized value can be calculated. Non-weather dependent data should be subtracted from the raw consumption data before the weather normalization as described above is performed. After the normalization is performed, non-weather dependent data should be added to the normalized values in order to obtain a more accurate weather normalized value. *Table 3.3* below shows the same data for Eagle Hall as shown in *Table 3.2*, with the addition of consumption values with non-weather dependent consumption for 2007-2008 and 2008-2009 removed. The non-weather dependent consumption for 2008-2009 was calculated using the same method as described for 2007-2008.

Table 3.3: Natural Gas Consumption for Eagle Hall Adjusted for Non-Weather Dependent Consumption.

Year	Natural Gas Consumption (Ccf)	Non-Weather Dependent Consumption (Ccf)	Adjusted Consumption (Ccf)
(07-08)	33372	732.9	32639
(08-09)	35466	1580.2	33886

The weather normalization is performed in the same manner as described above, with the addition of calculated non-weather dependent consumption data to the normalized consumption values to obtain a more accurate figure. *Table 3.4* below shows the weather normalized values minus non-weather dependent consumption, and then the values with the non-weather dependent consumption for each of the years added in.

Table 3.4: Weather Normalized Natural Gas Consumption for Eagle Hall Using Regression Method.

Year	Adjusted Consumption (Ccf)	HDD	Ccf/HDD	Avg. HDD	Normalized Consumption (Ccf)	Normalized Consumption Plus NWD (Ccf)
(2007-08)	32639	4911	6.65	5333	35444	36177
(2008-09)	33886	5358	6.32	5333	33728	35308

The weather normalized values using this linear regression method produced results very similar as the simple ratio-based weather normalization, but this is due to the fact that natural gas is only use for hot water and space heating in Eagle Hall. The non-weather dependent consumption represents a small portion of total consumption values. If an energy source is used to operate a higher percentage of non-weather-dependent functions, the results may be quite different. Weather normalization is subject to other problems that can affect the accuracy of the results as well.

There are five problems that affect the accuracy of weather normalization;

1. Base-temperature issues,

2. Issues with non-weather dependent energy calculations,

3. Intermittent heating issues,

4. Meter reading issues, and

5. “Ideal” temperature problems. (Bizzee Software Ltd, 2011)

The base-temperature problem concerns the value of the base-temperature or "balance point[7]" in a building. (Bizzee Software Ltd, 2011) The balance point or base-temperature is supposedly the outside temperature above or below which the building does not require heating or cooling. In the United States this is commonly set at 65°F, however not all buildings operate at this base temperature – different buildings have different base temperatures and these base temperatures can change throughout the year. (Bizzee Software Ltd, 2011) The base temperature affects the number of degree days in the calculations and can have a proportionally large impact on weather normalization calculations if the base temperature is carefully chosen. (Bizzee Software Ltd, 2011)However, due to the fact that base temperature can – and often does – change throughout the year, even the most appropriate base temperature is only an approximation. (Bizzee Software Ltd, 2011)

As shown above, non-weather dependent energy consumption needs to be removed from consumption values before they can be weather normalized. The method described above is based on a 65°F base temperature, however as the base temperature changes, the non-weather dependent consumption calculated by this method changes as well. Not only can the base temperature affect non-weather dependent calculations, but the values themselves will change from year to year based on seasonal or even daily changes. (Bizzee Software Ltd, 2011) For example, lighting energy consumption usually depends on the level of daylight which can vary from day to day and season to season. (Bizzee Software Ltd, 2011) Non-weather dependent consumption calculation is an approximation that can affect the accuracy of the weather normalized data.

Intermittent heating concerns the fact the most buildings are only heated to full temperature intermittently around occupancy hours. (Bizzee Software Ltd, 2011) This is less of a

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[7] Note that the "balance point" takes building internal gains into consideration; therefore, it is usually lower than the base temperature.

concern in residence halls due to the fact that they are generally occupied 24 hours a day 7 days a week during the school year; however the no occupancy periods during holidays can affect the accuracy of weather normalization. The degree day data is generally for months or years, and lack of consumption during times of no occupancy can skew the data.

The meter reading problem concerns when meter readings are taken on energy consumption in relation to the degree day data. The degree days are for fixed periods of time, and for accurate results the consumption values must be for those same periods. Ideally, meter readings should be taken at 12:00 AM at the change of a period to ensure proper alignment of the degree days and consumption. (Bizzee Software Ltd, 2011) However, meter readings are generally taken when it is convenient – a couple of days early or late in the case of weekends, holidays, or simply when facilities management can get to it. (Bizzee Software Ltd, 2011)

The final problem associated with weather normalization has to do with “ideal” temperature. When the outside temperature is close to the base temperature, buildings will often not require heating or cooling. (Bizzee Software Ltd, 2011) However, any differences in temperature are recorded by degree day data, whether the building required space heating and cooling or not. (Bizzee Software Ltd, 2011) This may also add inaccuracy to weather normalization of consumption data.

Despite these issues, weather normalization is a crucial part of energy use monitoring and energy management. As long as the inaccuracies are understood and accounted for and the reliability of the data is taken into consideration when basing decisions on the data, weather normalization can help identify areas that have seen improvement, and where efforts need to be concentrated in order to make more substantial improvements.

4. Combining Weather dependent data and non-weather dependent data to build load profiles

Once the weather-dependent energy sources have had their non-weather dependent portions removed, the weather-dependent portions normalized, and the non-weather dependent portions added back into the usage data, it is possible to combine energy sources for the purposes of estimating a total energy load profile for the building. In the case of the James Madison University campus, this involves combing electricity with either steam or natural gas to produce a total energy usage load profile. In order to consolidate all energy sources into a single total for purposes of load profiling, they must be converted to a common unit of measure. The British thermal unit (Btu) is the most conventional measure for these purposes. JMU electricity data is reported in kilowatt hours (KWh), natural gas data in one hundred cubic feet (Ccf), and steam in one thousand pounds (klbs).

Figure 3.3 displays the electricity consumption for Eagle Hall for the fiscal year 2005-2006. The consumption values of kWh were converted to Btu by multiplying the values by the conversion of 3412.142 Btu per kWh and then divided by 1,000,000 to obtain MMBtu[8] per Month. *Figure 3.4* contains the weather adjusted natural gas consumption of Eagle Hall for the fiscal year 2005-2006. These values were multiplied by the conversion rate of 102,000 Btu per Ccf of natural gas, and again divided by 1,000,000 to obtain MMBtu per Month. Finally, these monthly consumption values were added together to obtain total energy consumption per month in MMBtu as shown in *Figure 3.5*.

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[8] MMBtu or Millennium Millennium Btu as used in the United States Customary Units system.

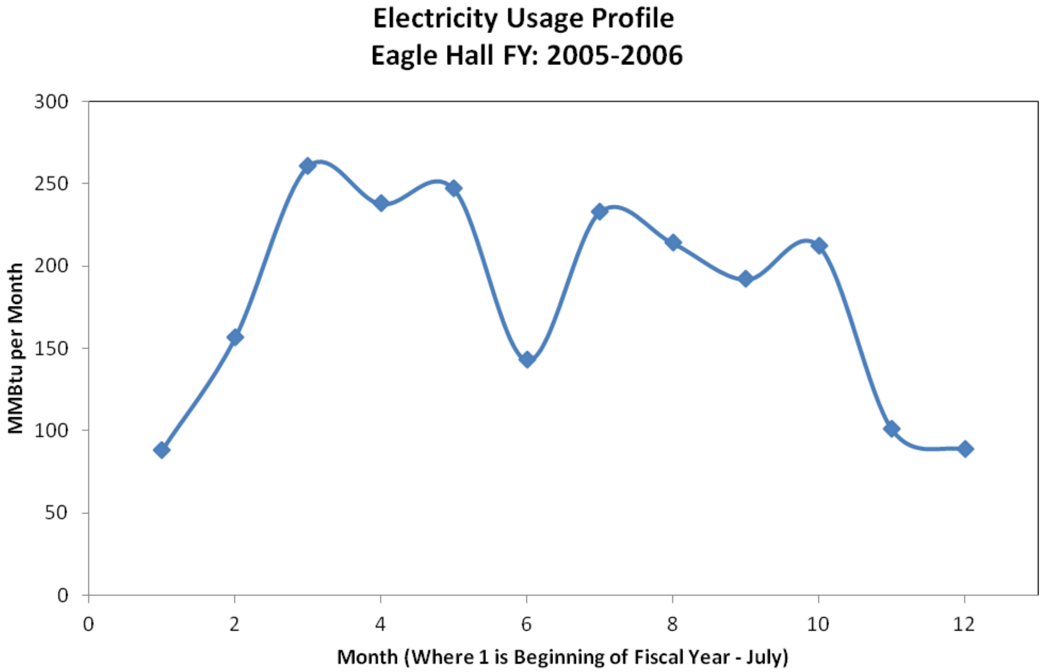


Figure 3.3: Electricity Usage Profile for Eagle Hall for Fiscal Year 2005-2006

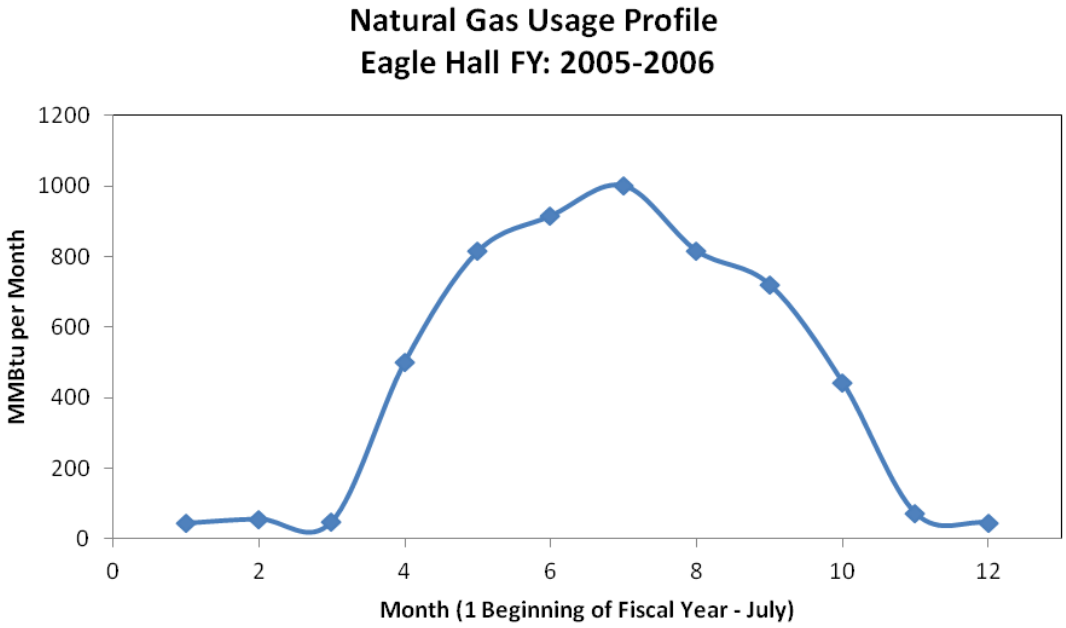


Figure 3.4: Weather Adjusted Natural Gas Usage Profile for Eagle Hall for Fiscal Year 2005-2006.

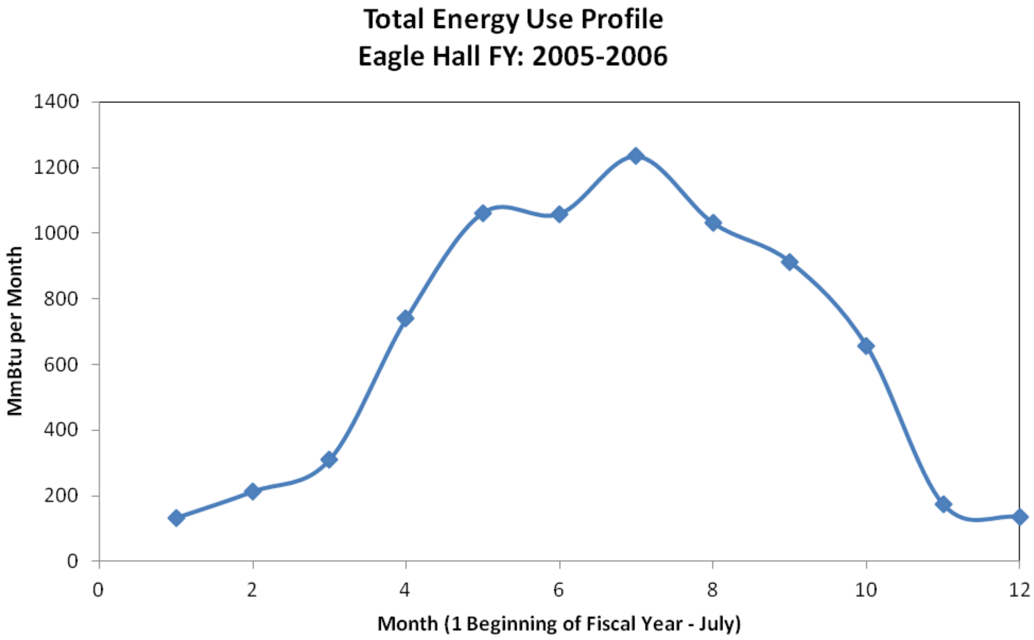


Figure 3.5: Total Energy Usage Profile for Eagle Hall for Fiscal Year 2005-2006.

The process for combining steam energy usage to electricity is a little different due to the unique properties of steam. Steam usage data at JMU is provided in kilo-pounds, or klbs, of steam. In order to convert steam usage in klbs to Btu it is necessary to know the quality of the steam and the pressure and temperature at which it is delivered. In a paper by Dr. Jonathan Miles of James Madison University titled *Dual Roles of Infrared Imaging on a University Campus: Serving the Physical Plant while Enhancing a Technology-Based Curriculum*, he states that the east campus steam plant is designed to provide saturated steam at 383°F and 200 psia. With this information in hand it is possible to convert the steam energy usage data from klbs to Btu.

Using Engineering Equation Editor, and the absolute pressure and temperature values obtained above, one can find that the Btu/lb value for the slightly superheated steam provided by the east campus plant is 1,200. This value is multiplied by 1000 to obtain the Btu/klbs value of 1,200,000. The final step is to multiply the weather adjusted steam energy usage values by this value to obtain usage in Btu. *Figure 3.6* is the steam usage profile for Potomac Hall in MMBtu per Month for the 2005-2006 fiscal year.

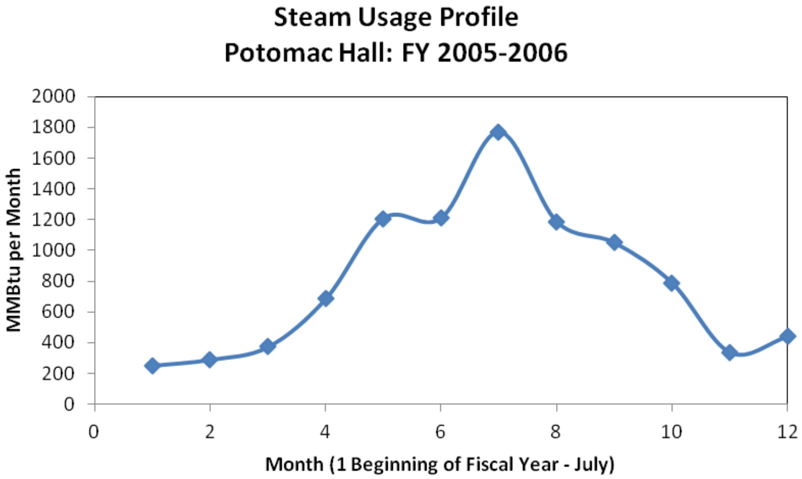


Figure 3.6: Steam Energy Usage Profile for Potomac Hall for the Fiscal Year 2005-2006.

Finding the total energy usage values combining steam and electricity usage data is the same process as combining electricity and natural gas, simply add them together to get a combined total usage. *Figure 3.7* shows the total energy load profile for Potomac Hall in MMBtu per Month for the 2005-2006 fiscal year.

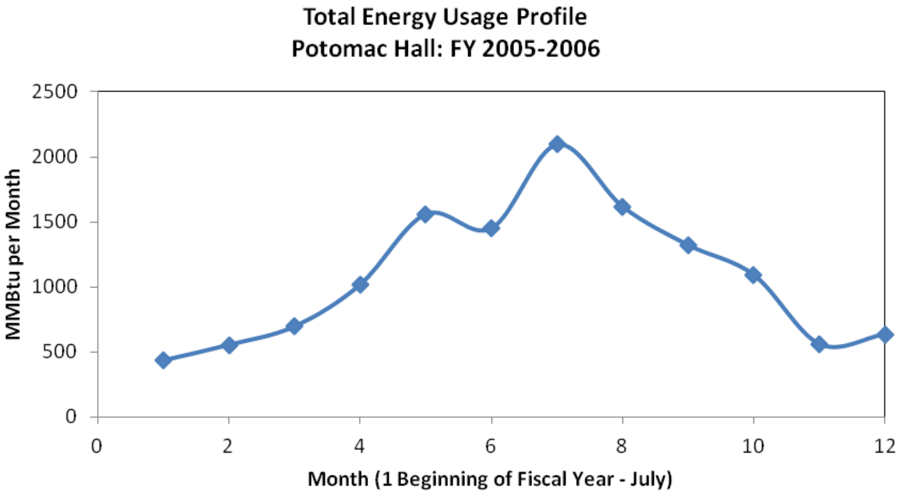


Figure 3.7: Total Energy Load Profile for Potomac Hall: FY 2005-2006.

The load profile of a building is broken up into two distinct parts, the baseload, which in this case refers the total amount of energy a building uses at all times, and the variable load, which is the load that varies throughout the year. The energy use of a building is the area underneath the curve in the load profile. The baseload is simply the lowest point on the load profile, drawn across the whole time series, as shown in *Figure 3.8* below. Anything above that point is the variable load for the building.

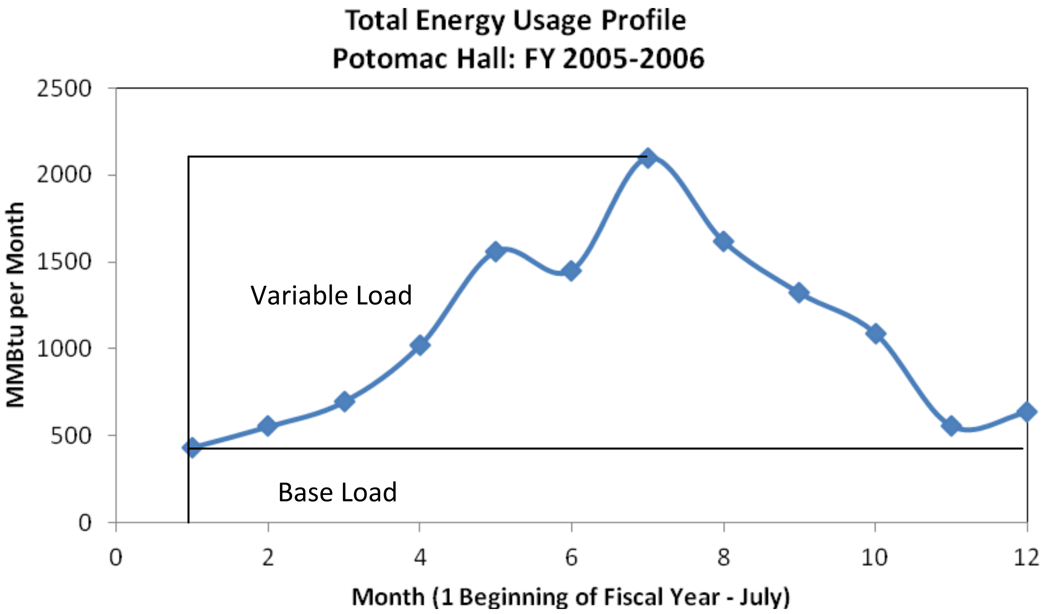


Figure 3.8: Total Energy Usage for Potomac Hall: FY 2005-2006.

5. **Estimating Individual Energy Loads without Direct Load Measurement Data**

There are multitudes of energy efficiency and conservation measure that can be implemented in any of the various building systems available. In order to focus the efforts on where they will have the greatest impact, it is crucial to know which of the energy using systems in the building comprise the greatest percentage of total energy usage. Otherwise, funds may be used on projects that have little overall effect on the total building energy consumption. For instance, replacing all the lights in a building with energy efficient bulbs may have an effect on total energy use in the building, but if lighting only represents a small portion of the total energy use, the savings may not be as great as expected. This information is normally presented graphically in a pie chart format.

This sort of analysis can be completed automatically by an advanced metering and dashboard program. However, in the absence of these programs, these percentages can be estimated. It is essential however to realize that these will be just estimations, and the accuracy of these estimations is directly tied to the accuracy and attention to detail in generating them. Despite the limitations of the accuracy of these analyses, they are well suited to giving an overall picture of the energy usage of the building and directing energy efficiency and conservation efforts.

The previous sections on weather normalization and non-weather dependent load analysis effectively separates the domestic hot water from the space heating loads in the JMU buildings. Although these estimates are based on only one month of data for which we can fully isolate hot water from heating energy use, the techniques do effectively differentiate the magnitude of these end use energy needs. Load analysis for electricity consumption is more complicated, but possible, in the absence of direct load measurement.

The first step in the process of generating energy percentage breakdowns is to take as complete an inventory of the energy using equipment in the building as possible. For the purposes of this project, an inventory of all lights, vending machines, kitchen equipment, washers and dryers by type, location, and electric consumption was created for each residence hall. These inventories were generated by two undergraduate students as a part of the overarching grant that this project is a part of.

Table 3.5 below contains an example of the lighting inventory for Chappelear Hall in the Village area on the JMU Campus. *Table 3.6* contains a portion of the lighting guide that the lighting inventory was based on, also developed by the undergraduate students. It contains information on the type of light fixture, lightbulbs per fixture, and wattage. The daily electric load for lighting, vending machines, kitchen appliances, and student plug loads can be estimated by taking the watt draw of any given piece of equipment and multiplying it by the number of hours in use per day to obtain watt-hours per day. For lighting, three estimations in hours usage per day were created, conservative, moderate, and flagrant. *Table 3.7* shows the flagrant usage breakdown for Eagle Hall in the Lake Hall area of the JMU campus. This spreadsheet contains area of the building, fixture type, watts per fixture, hours in use per day on average, and the watt-hours per day in energy consumption by lighting for that area of the building and the total energy consumption for the entire building based on the estimated hours per day usage of those lights. The goal is a total kilowatt-hour per day figure based on that lighting use estimation.

Table 3.5: Lighting Inventory for Chappelear Hall.

Student Rooms		**Notes/Comments**		**Hallways**		**Notes/Comments**
Total Bedrooms	99	Not inculding Room 100 of each section		Resident Hallways		
Fixture Type in Bedroom	A			Total Hallways	18	
Fixtures per Bedroom	1			Fixture Type in Hallway	D	
				Fixtures per Hallway	4	1 Sercurity Light
Total Common Rooms	33			Total LED Exit Signs	5	3 Fixtures controled by 1 Switch
Fixture Type in Common Room	A			Total Incandescent Exit Signs	11	
Fixtures per Common Room	1			Total Florescent Exit Signs	2	
Room 100 (A,B,C sections)				**Basement Hallway (C section)**		
Fixture Type	A	No common room.		Fixture Type in Hallway	A	Possible A/C in storage room
Number of Fixtures	3			Fixtures per Hallway	5	Air Handling Equipment
				Incandescent Exit Signs	1	
Stairwells				LED Exit Signs	1	
				Florescent Exit Signs	1	
Total Stairwells	6					
Fixture Type in Stairwells	D,E			**Foyer Hallways**		
Total D Fixtures	5			Total Foyer Hallways	3	
E Fixtures per Stairwell	4			Fixture Type in Foyer Hallway	A	
Total LED Exit Signs	1			Fixtures per Foyer Hallway	3	
Total Incandescent Exit Signs	3			Total LED Exit Signs in all Foyer's	5	
Total Florescent Exit Signs	2			Total Florescent Exit Signs in all Foyer's	1	
Bike Room + (B Section) Hallways to Basement				**Bathrooms**		
				Total Bathrooms	15	All bathrooms had motion sensors
Fixture Type in Bike Room	A			Fixture Type in Bathroom	B,C	
Fixtures in Bike Room	8	1 Sercurity Light		B Fixtures per Bathroom	2	
Incandescent Exit Signs	4	3 Fixtures controled by 1 Switch		C Fixtures per Bathroom	1	
Recycle Room				**1st Floor Mini bathrooms**		
				Number of Mini bathrooms	3	
Fixture type in Recycle Room	A			Type of Fixtures per bathroom	A,B,C,D	
Fixtures in Recycle Room	1			Total A Fixtures	1	
				Total B Fixtures	3	
Study Lounge + Study Room				Total C Fixtures	3	
				Total D Fixtures	6	

Table 3.6: Lighting Guide for the Village Area Residence Halls.

Fixture A	Fluorescent U-tube
Total Number of Tubes in Fixture A	2
Watts per Tube in Fixture A	35 W
Fixture B	4 ft (T-12) 1.5 in diameter
Total Number of Tubes in Fixture B	2
Watts per Tube in Fixture B	20 W
Fixture C	2 ft (T-12) 1.5 in diameter
Total Number of Tubes in Fixture C	2
Watts per Tube in Fixture C	20 W
Fixture D	Compact Fluorescent
Total Number of Lamps in Fixture D	1
Watts per Lamp in Fixture D	13 W
Fixture E	4 ft (T-12) 1.5 in diameter
Total Number of Tubes in Fixture E	2
Watts per Tube in Fixture E	34 W
Fixture F	2 ft (T-8)
Total Number of Tubes in Fixture F	2
Watts per Tube in Fixture F	34 W
Fixture G	2 Compact Fluorescent
Total Number of Lamps in Fixture G	2
Watts per Lamp in Fixture G	13 W
Fixture H	4 ft (T-8)
Total Number of Tubes in Fixture H	2
Watts per Tube in Fixture H	32 W

Table 3.7: Flagrant Lighting Electricity Consumption for Eagle Hall.

EAGLE HALL Flagrant Light Use. Little or no Concern for conservation- Based on Data from Blackboard Site

Student Rooms	
# of Rooms	240 (275)
Fixture Type	E
Fixtures per Room	1
Total Fixtures	275
Watts per Fixture	70
Hours in Use (avg hrs/day)	12
Wh per day	231000
Total Wh per day	231000

Stairwells	
# of Stairwells	2
Fixture Type	C
Fixtures per Stairwell	18
Total Fixtures	36
Watts per Fixture	64
Hours in Use (avg hrs/day)	24
Wh per day	55296
Total LED Exit Signs	2
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Wh per day	192
Total Wh per day	55488

Recycle Room	
Fixture type	E,F
# of E Fixtures	3
Watts per Fixture	70
Hours in Use (avg hrs/day)	24
Wh per day	5040
# of F Fixtures	1
Watts per Fixture	112
Hours in Use (avg hrs/day)	24
Wh per day	2688
Incandescent Exit Sign	1
Watts per Fixture	40
Hours in Use (avg hrs/day)	24
Wh per day	960
Total Wh per day	8688

Study Lounge	
Fixture Type	B,E
# of B Fixtures	24
Watts per Fixture	68
Hours in Use (avg hrs/day)	5
Wh per day	8160
# of E Fixtures	3
Watts per Fixture	70
Hours in Use (avg hrs/day)	5
Wh per day	1050
Total Wh per day	9210

Laundry Room	
Fixture Type	E
Total # of E Fixtures	8
Watts per Fixture	70
Hours in Use (avg hrs/day)	24
Wh per day	13440
Total Wh per day	13440

Kitchen	
Fixture type	D,E
# of D Fixtures	2
Watts per Fixture	128
Hours in Use (avg hrs/day)	5
Wh per day	1280
# of E Fixtures	1
Watts per Fixture	70
Hours in Use (avg hrs/day)	5
Wh per day	350
Total Wh per day	1630

Elevator	
Number of Elevators	2
Lights in Elevator	LED (9)
Total Fixtures	18
Watts per Fixture	2
Hours in Use (avg hrs/day)	24
Wh per day	864
Total Wh per day	864

Hallways	
Resident Hallways	
# of Hallways	30
Fixture Type	E
Fixtures per Hallway	3
Total Fixtures	90
Watts per Fixture	70
Hours in Use (avg hrs/day)	24
Wh per day	151200
Total LED Exit Signs	2
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Wh per day	192
Wing Connecting Hallways 2nd-8th floors	
# of Connecting Hallways	7
Fixture Type	E
# of E Fixtures per Connecting Hallway	8
Total Fixtures	56
Watts per Fixture	70
Hours in Use (avg hrs/day)	24
Wh per day	94080
Total LED Exit Signs in all Foyer's	14
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Wh per day	1344
Basement Hallway	
Fixtures in basement Hallways	E
# of E Fixtures in Basement Hallways	13
Total Fixtures	13
Watts per Fixture	70
Hours in Use (avg hrs/day)	24
Wh per day	21840
LED Exit Signs	3
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Wh per day	288
Total Wh per day	268944

Bathrooms	
Total Bathrooms	16
Fixture Type in Bathroom	C
# of C Fixtures per Bathroom	5
Total Fixtures	80
Watts per Fixture	64
Hours in Use (avg hrs/day)	24
Wh per day	122880
Basement Bathrooms	
Type of Fixture	C
# of C Fixtures	2
Watts per Fixture	64
Hours in Use (avg hrs/day)	24
Wh per day	3072
TV Lounge Bathroom	
Fixture Type	C
Total # C Fixtures	1
Watts per Fixture	64
Hours in Use (avg hrs/day)	24
Wh per day	1536
Total Wh per day	4608

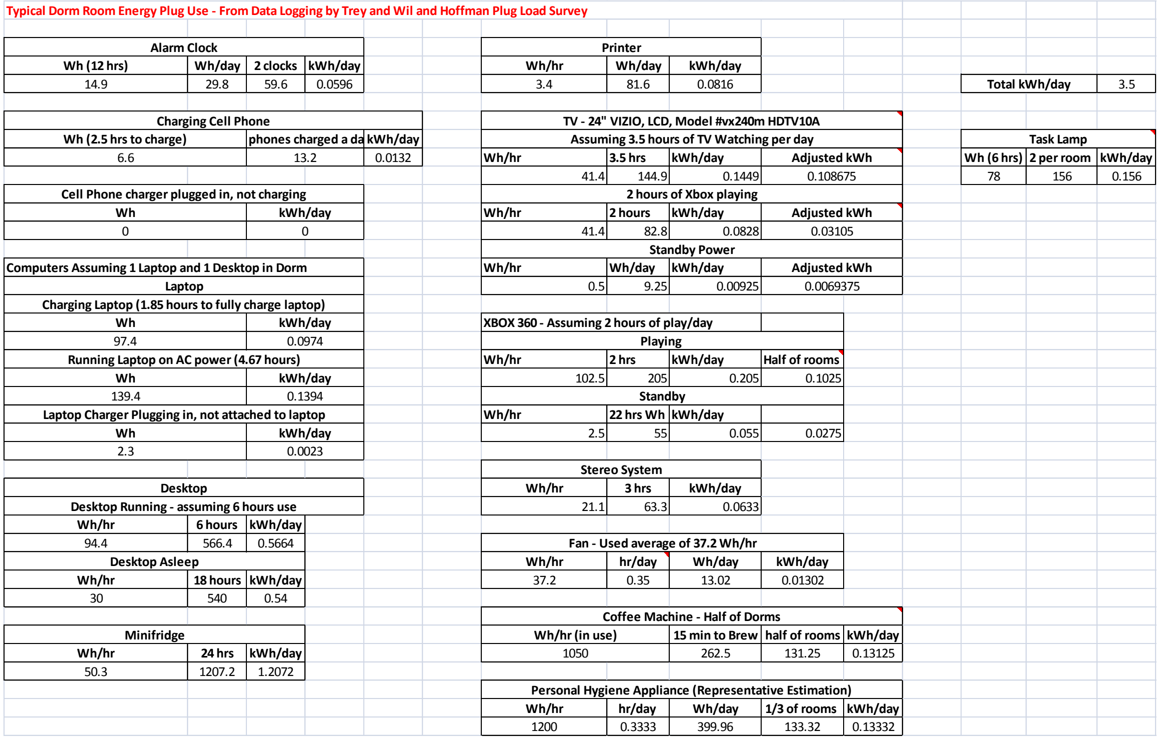
Dorm Office	
Fixture Type In Dorm Office	
Fixtures in Dorm Office	
Total Fixtures	
Watts per Fixture	
Hours in Use (avg hrs/day)	
Wh per day	
Total Wh per day	

Entrance Room + TV Lounge	
Fixture Type in TV Lounge	D,E
Total # D Fixtures in TV Lounge	10
Watts per Fixture	128
Hours in Use (avg hrs/day)	10
Wh per day	12800
Total # E Fixtures in TV Lounge	9
Watts per Fixture	70
Hours in Use (avg hrs/day)	10
Wh per day	6300
LED Exit Signs	3
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Wh per day	288
Total Wh per day	19388

Total Wh per day of Building	739212
kWh	739.212

The next step is to generate the energy consumption value for a typical dorm room. *Table 8* contains the appliances, their usages and electricity loads, and estimated watt-hours per day of usage. These watt-hour consumptions were added together to obtain a total energy usage per day value for a "typical" dorm room on the JMU campus.

Table 3.8: Typical Dorm Room Energy Consumption.



Typical Dorm Room Energy Plug Use - From Data Logging by Trey and Wil and Hoffman Plug Load Survey

Alarm Clock			
Wh (12 hrs)	Wh/day	2 clocks	kWh/day
14.9	29.8	59.6	0.0596

Charging Cell Phone		
Wh (2.5 hrs to charge)	phones charged a da	kWh/day
6.6	13.2	0.0132

Cell Phone charger plugged in, not charging	
Wh	kWh/day
0	0

Computers Assuming 1 Laptop and 1 Desktop in Dorm	
Laptop	
Charging Laptop (1.85 hours to fully charge laptop)	
Wh	kWh/day
97.4	0.0974
Running Laptop on AC power (4.67 hours)	
Wh	kWh/day
139.4	0.1394
Laptop Charger Plugging in, not attached to laptop	
Wh	kWh/day
2.3	0.0023

Desktop		
Desktop Running - assuming 6 hours use		
Wh/hr	6 hours	kWh/day
94.4	566.4	0.5664
Desktop Asleep		
Wh/hr	18 hours	kWh/day
30	540	0.54

Minifridge		
Wh/hr	24 hrs	kWh/day
50.3	1207.2	1.2072

Printer		
Wh/hr	Wh/day	kWh/day
3.4	81.6	0.0816

TV - 24" VIZIO, LCD, Model #vx240m HDTV10A			
Assuming 3.5 hours of TV Watching per day			
Wh/hr	3.5 hrs	kWh/day	Adjusted kWh
41.4	144.9	0.1449	0.108675
2 hours of Xbox playing			
Wh/hr	2 hours	kWh/day	Adjusted kWh
41.4	82.8	0.0828	0.03105
Standby Power			
Wh/hr	Wh/day	kWh/day	Adjusted kWh
0.5	9.25	0.00925	0.0069375

XBOX 360 - Assuming 2 hours of play/day			
Playing			
Wh/hr	2 hrs	kWh/day	Half of rooms
102.5	205	0.205	0.1025
Standby			
Wh/hr	22 hrs Wh	kWh/day	
2.5	55	0.055	0.0275

Stereo System		
Wh/hr	3 hrs	kWh/day
21.1	63.3	0.0633

Fan - Used average of 37.2 Wh/hr			
Wh/hr	hr/day	Wh/day	kWh/day
37.2	0.35	13.02	0.01302

Coffee Machine - Half of Dorms			
Wh/hr (in use)	15 min to Brew	half of rooms	kWh/day
1050	262.5	131.25	0.13125

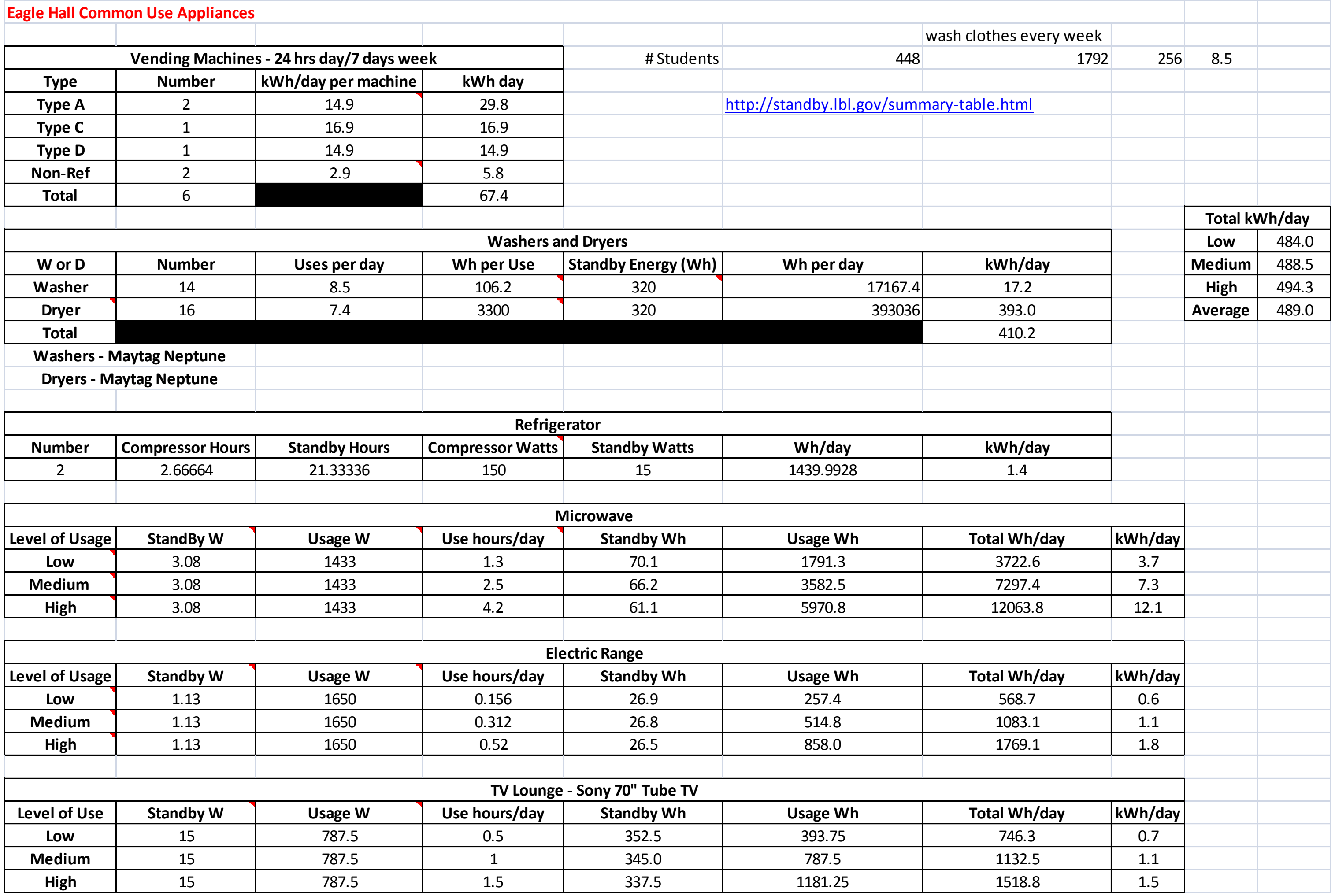
Personal Hygiene Appliance (Representative Estimation)				
Wh/hr	hr/day	Wh/day	1/3 of rooms	kWh/day
1200	0.3333	399.96	133.32	0.13332

Total kWh/day	3.5

Task Lamp		
Wh (6 hrs)	2 per room	kWh/day
78	156	0.156

After student plug loads, the next part was to estimate the energy consumption of common use appliances in the residence halls. This includes vending machines, washers and dryers, refrigerators, ranges, microwaves and public use televisions. Information on these appliances was collected at the same time as the lighting data for each of the residence halls. *Table 3.9* contains an example of the spreadsheet analysis of common use appliance energy consumption for Eagle Hall. For each of the appliances a kWh/day value was calculated based on the energy draw from the data logging experiments and an estimated usage per day. Finally, as with the student plug loads, a total energy usage per day value was generated for the common use appliances.

Table 3.9: Common Use Appliance Energy Consumption for Eagle Hall.



Eagle Hall Common Use Appliances

Vending Machines - 24 hrs day/7 days week			
Type	**Number**	**kWh/day per machine**	**kWh day**
Type A	2	14.9	29.8
Type C	1	16.9	16.9
Type D	1	14.9	14.9
Non-Ref	2	2.9	5.8
Total	6		67.4

		wash clothes every week		
# Students	448	1792	256	8.5

http://standby.lbl.gov/summary-table.html

Total kWh/day	
Low	484.0
Medium	488.5
High	494.3
Average	489.0

Washers and Dryers						
W or D	**Number**	**Uses per day**	**Wh per Use**	**Standby Energy (Wh)**	**Wh per day**	**kWh/day**
Washer	14	8.5	106.2	320	17167.4	17.2
Dryer	16	7.4	3300	320	393036	393.0
Total						410.2

Washers - Maytag Neptune

Dryers - Maytag Neptune

Refrigerator						
Number	**Compressor Hours**	**Standby Hours**	**Compressor Watts**	**Standby Watts**	**Wh/day**	**kWh/day**
2	2.66664	21.33336	150	15	1439.9928	1.4

Microwave							
Level of Usage	**StandBy W**	**Usage W**	**Use hours/day**	**Standby Wh**	**Usage Wh**	**Total Wh/day**	**kWh/day**
Low	3.08	1433	1.3	70.1	1791.3	3722.6	3.7
Medium	3.08	1433	2.5	66.2	3582.5	7297.4	7.3
High	3.08	1433	4.2	61.1	5970.8	12063.8	12.1

Electric Range							
Level of Usage	**Standby W**	**Usage W**	**Use hours/day**	**Standby Wh**	**Usage Wh**	**Total Wh/day**	**kWh/day**
Low	1.13	1650	0.156	26.9	257.4	568.7	0.6
Medium	1.13	1650	0.312	26.8	514.8	1083.1	1.1
High	1.13	1650	0.52	26.5	858.0	1769.1	1.8

TV Lounge - Sony 70" Tube TV							
Level of Use	**Standby W**	**Usage W**	**Use hours/day**	**Standby Wh**	**Usage Wh**	**Total Wh/day**	**kWh/day**
Low	15	787.5	0.5	352.5	393.75	746.3	0.7
Medium	15	787.5	1	345.0	787.5	1132.5	1.1
High	15	787.5	1.5	337.5	1181.25	1518.8	1.5

With these usages per day values in hand for the electricity consumption of the various dorms, a total energy breakdown chart could be created for each of the dorms. For electricity, the lighting, student plug loads, and common use appliance energy usage per day for a particular residence hall were multiplied by the school days in a typical school year to obtain total energy consumption from those end uses. That value was then subtracted from the total electricity usage for the school year of a particular dormitory to obtain the process power, which is all unaccounted for electricity usage in that residence hall; assumed to be fans, blowers, heating equipment, etc.

6. Constructing the Complete Load Profile

The final step is the construction of the completed load profile. Once the lighting, student plug loads, common use appliance loads, and process power values have been generated, they can be combined to generate a pie chart of percentage of total energy consumption by end use contribution of consumption. These four electricity usage values were converted to Btu and along with the Btu values from natural gas or steam consumption for space heating and hot water used to create charts similar to that shown for Chappelear Hall in *Figure 3.9.*

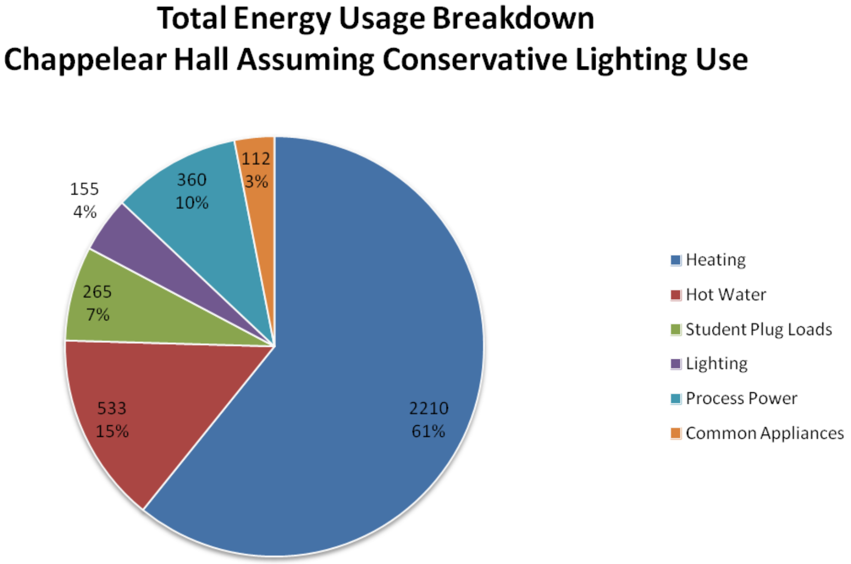


Figure 3.9: Example of Total Energy Use Breakdown for Chappelear Hall.

This chart contains the percentage of total energy consumption that each of the end uses are responsible for, in this case assuming conservative lighting usage, as well as the energy consumption for that end use in MMBtu. This chart indicates that the majority, 61%, Btu usage is attributed to heating of the residence hall. The next largest consumption, 15%, is a result of domestic hot water consumption. The electricity usages are each responsible for 10% or less of Btu consumption, with the largest portion being attributed to process power. Student plug loads are responsible for 7% of consumption, 4% of consumption attributed to lighting, and 3% to common use appliances.

It is through these charts that the areas that would benefit most from energy saving options (ESO) can be identified and initiatives that will have the most impact can be decided. This chart indicates that ESO's aimed at reducing heating and hot water loads would have the most impact on reducing Btu consumption in the residence hall despite focus generally being on reducing lighting loads or plug loads, which are a small portion of total Btu consumption.

Summary

The methodology presented in this Chapter is meant to be an example of guidelines that can be used to estimate energy consumption values on university residence halls and are the steps taken to complete the analysis in this project. The steps to this methodology are;

1. **Data Collection –** Available data is collected and compiled into an easily manipulated format for the purposes of further analysis.
2. **Non-weather Dependent Data Estimation –** Energy usage data are adjusted to remove non-weather dependent consumption from weather dependent consumption. This is accomplished in one of two ways, either through the use of periods of time where energy sources can easily be broken apart into their separate components – September steam and natural gas consumption on the JMU Campus - or through the linear regression analysis.

3. **Weather Normalization –** Weather dependent consumption is adjusted to account for differences in heating and cooling degree days from year to year. After the data has been weather adjusted, non-weather dependent data is added to the adjusted values to get a new consumption value for a specified period of time. This process allows fair comparison of consumption between years to account for variations in climate.
4. **Combination of Energy Consumption for Different Energy Sources for Complete Usage Profiles –** The different energy sources for a building are compiled together by converting all consumption values to a common unit, Btu in this case, to generate total energy usage profiles which describe the changes in consumption over time.
5. **Estimating Individual Loads without Direct Load Measurement –** The consumption of various end uses are estimated by conducting load inventory of the different building sub-systems such as lighting, student plug loads, common use appliances, and process power. An energy consumption per day for each of these loads is estimated for the purposes of generating total consumption due to these end uses for a specified period of time.
6. **Construction of the Complete Load Profile –** End use consumption is compiled together into a single pie chart to generate percentage contributions toward total energy consumption. This information can be used to determine the areas of end use consumption that will benefit the most from energy conservation options to reduce consumption of the building as a whole.

The data analysis up to step 5 is based on actual metered data and well-defined processes for weather normalization. The data analysis for steps 5 and 6 is based on assumptions on individual end use consumption from inventories and assumed usages. The student plug load assumptions for this project have been based on previous projects as part of the overarching grant that this project is a part of. The appliances chosen for this analysis are based on a series of data logging experiments conducting by two undergraduate students as part of the EPA grant that this thesis is a part of as well as an informal plug load audit conducted on Hoffman Hall in the spring of 2009. The results of this plug load audit can be found in *Table 3.10*. From the plug load audit, the appliances or electronics with the largest instances of occurrence in Hoffman Hall were chosen for inclusion into the "typical" dorm room. This includes a television, in 75% of rooms, a game system in 50% of rooms, two computers per room (a desktop and a laptop for this analysis), a printer in every room, two alarm clocks in every room, a coffee maker in 50% of the rooms, two task lamps per room, and a personal hygiene appliance in 33% of all rooms. Additionally, a stereo system, an oscillating fan, and a mini-fridge were also assumed to be present in all dorm rooms. Energy consumption values from either the data logging experiments or from www.energysavers.gov were used in conjunction with estimates on appliance use per day to generate a kilowatt-hour per day value for each of the appliances.

Table 3.10: Results of Hoffman Hall informal Plug Load Audit – Spring 2009.

Category	Number of Devices	Category	Number of Devices
Entertainment/Music		**Food**	
TV	25	Refrigerator	39
Game systems	16	Coffee Maker	12
Radio	4	Hotpot/Water Heater	7
Ipod decks	8	Magic Bullet/Blender	1
Speakers	15		
Amp	2	**Lights**	
VCR	2	Lamps	63
Camera	15	Christmas Lights	2
Fish Tank	1		
DVD Player	12	**Hygiene/Grooming**	
Guitar Pedals	1	Hair Dryer	27
Keyboard	1	Straighteners	21
		Fans	19
Academic		Curling Iron	4
Computers/Chargers	68	Electric Rollers	1
Printers	68	Humidifier	1
Clocks	49	Vanity Mirror	2
Phone Chargers	68	Vacuum Cleaner	2
Power strips	23	Air Purifiers	2
Pencil Sharpener	2	Clothes Iron	1
Battery Charger	2	Air Fresheners	2
		Electric Toothbrush	4
		Razor	2

Chapter 4: Data Analysis

Overview of Chapter

Chapter four of this report is the data analysis of the energy usage of the four residence halls using the monthly data for each of the three energy types, depending on the individual makeup of each dormitory, and the methodology outlined in Chapter three. The purpose of this data analysis is to generate information regarding the total energy usage profiles for each of the residence halls for comparison with other dormitories and subsequent year of consumption. Additionally, charts regarding the percentage contribution towards total energy consumption were generated for the purposes of determining the end uses that will benefit the most from energy saving options (ESO) toward reduction of overall energy consumption in the building. The charts are all generated without data from advanced metering or sub-metering systems and are an attempt to describe the sort of information that can be generated in the absence of these systems when only building level metered data is available. For each residence hall the data for the fiscal year 2005-2006 was analyzed to generate load profiles for electricity, steam or natural gas, and total energy use, except for Converse Hall, in which the fiscal year 2006-2007 was used due to an issue with the steam meter and consequent readings for the 2005-2006 fiscal year. Additionally, percentage breakdowns by end use for each energy source and total energy have been generated for the school year, September through April, for each of the four residence halls. This chapter is broken down by energy source; natural gas, steam, electricity, and total energy, the energy usage indexes – usage per square foot of building space and usage per resident - for each of the residence halls for the 2005-2006 fiscal year (except for Converse Hall, in which the 2006-2007 fiscal year was used), and contains the load profiles and percentage breakdown charts for the residence halls using that particular energy source.

Natural Gas

The two residence halls analyzed in this project using natural gas are Eagle Hall in the Lake Side area and Chappelear Hall in the Village area and is used in these residence halls for space heating and domestic hot water. The first step to the analysis was to weather adjust the natural gas usage based on the heating degree days seen in 2005-2006. The natural gas values are weather adjusted to allow comparison between other years for correction of changes in use as a result of differing climates from year to year. The values were only weather adjusted for October through April, because there is no heating in September on the JMU campus. In order to weather adjust, the baseline natural gas usage had to be determined and removed from the usage values for each month. For the purposes of this project, both the linear regression analysis method and using September usage values as the baseline usage weather adjustments were completed in order to allow a comparison between the values generated by the two methods.

Table 4.1 below shows the natural gas usage in hundreds of cubic feet (Ccf) for Eagle Hall by month of the year for 2005-2006, the Heating Degree Days (HDD) for that year from the Staunton Regional Airport weather station, the 5-year average HDD, and the 30-year average HDD. *Figure 4.1* shows the linear regression chart of HDD vs. Natural Gas Usage for Eagle Hall. The linear regression analysis returns the equation $y = 9.6709\,x + 93.825$ with an R^2 value of 0.9397, indicating a very good fit to the data. The y-intercept of the equation, 93.825, indicates that the baseline usage for this residence hall is 93.825 Ccf of natural gas per month using this analysis. The September usage for Eagle Hall is 485 Ccf of natural gas. These baseloads ideally represent the non-weather dependent usages for the residence hall, which for both halls is domestic hot water. *Table 4.2* shows the weather adjustment of the natural gas data using both the linear regression analysis baseline and the September baseline. The baseloads were first subtracted from the total usage for each month and new weather dependent usages were generated. Next the weather dependent usages were divided by the Heating Degree Days for that month to obtain Ccf of usage per HDD. Next the Ccf/HDD values were multiplied by the 30 year average for Heating Degree Days and the normalized weather dependent values were generated. Finally the baseloads for each of the months were added back into the value to get a normalized total natural gas usage value for each of the months of the year. Both methods result in very similar numbers, the values for each of the baseload methods have only a 900 Ccf difference between them for the entire years usage.

Table 4.1: Natural Gas Usage for Eagle Hall for the 2005-2006 fiscal year, Heating Degree days for that timeframe, 5-yr HDD averages and 30-yr averages.

	(2005-2006)		HDD Averages	
Month	**Ccf**	**HDD**	**Avg (5-yr)**	**Avg (30-yr)**
July	434	8	31.6	5
August	552	44	34.2	10
September	485	78	101.6	79
October	3985	287	350.6	364
November	6320	506	586.2	651
December	8949	932	870.6	935
January	6352	673	928.6	1070
February	6917	756	876.2	884
March	5997	598	614.6	714
April	2816	258	357	428
May	711	240	191	171
June	450	50	38	22
Annual	43968	4430	4980.2	5333

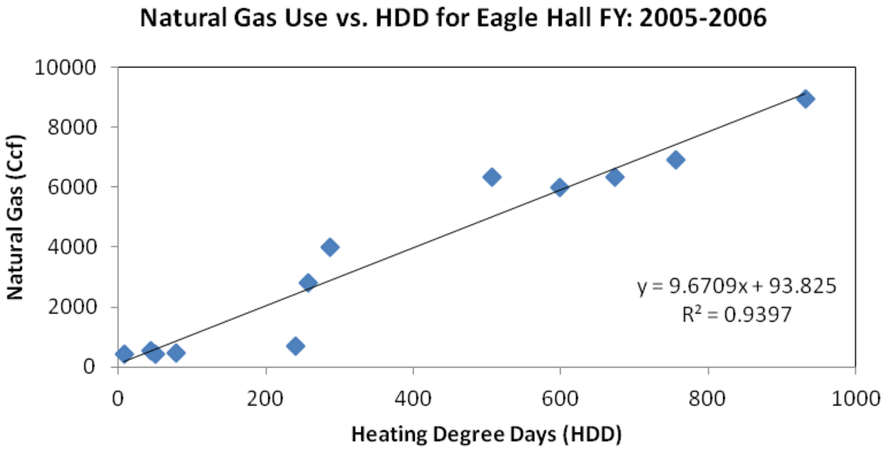


Figure 4.1: Natural Gas Usage vs. Heating Degree Days for Eagle Hall for the 2005-2006 fiscal year.

Table 4.2: Weather adjustment of Eagle Hall Natural Gas Usage data using both linear regression and September NWD values.

Month	Ccf Nat Gas	NWD (Ccf) Regression	Adjust Ccf Regression	HDD (05-06)	Ccf/HDD	Avg HDD (30-yr)	Norm Ccf - NWD	Norm CCf + NWD
October	3985	93.8	3891	287	13.56	364	4935	5029
November	6320	93.8	6226	506	12.30	651	8010	8104
December	8949	93.8	8855	932	9.50	935	8884	8978
January	6352	93.8	6258	673	9.30	1070	9950	10044
February	6917	93.8	6823	756	9.03	884	7978	8072
March	5997	93.8	5903	598	9.87	714	7048	7142
April	2816	93.8	2722	258	10.55	428	4516	4610

Month	Ccf Nat Gas	NWD Ccf (September)	Adjust (Ccf) From Sept	HDD (05-06)	Ccf/HDD	Avg HDD (30-yr)	Norm Ccf - NWD	Norm CCf + NWD
October	3985	485	3500	287	12.20	364	4439	4924
November	6320	485	5835	506	11.53	651	7507	7992
December	8949	485	8464	932	9.08	935	8491	8976
January	6352	485	5867	673	8.72	1070	9328	9813
February	6917	485	6432	756	8.51	884	7521	8006
March	5997	485	5512	598	9.22	714	6581	7066
April	2816	485	2331	258	9.03	428	3867	4352

Tables 4.3 and *4.4* show the adjusted natural gas usage for the year using both the regression and September baselines and the corresponding values in Btu and MMBtu. This same approach was used to weather adjust the natural gas usage values for Chappelear Hall in the Village area. *Figure 4.2* shows the raw and weather adjusted natural gas usage profiles for Eagle Hall and *Figure 4.3* shows the profiles for Chappelear Hall using both the linear regression and September non-weather dependent values as well as the raw values. The x-axis displays the month of the year in numbers, with 1 representing the beginning of the fiscal year, July.

Table 4.3: Adjusted Natural Gas Usage for Eagle Hall using linear regression weather adjusted data.

Month	Ccf	BTU	MMBtu
July	434	44268000	44.3
August	552	56304000	56.3
September	485	49470000	49.5
October	5029	512955326	513.0
November	8104	826626419	826.6
December	8978	915705386	915.7
January	10044	1024454577	1024.5
February	8072	823369149	823.4
March	7142	728493944	728.5
April	4610	470187483	470.2
May	711	72522000	72.5
June	450	45900000	45.9
Annual	54610	5570256284	5570

Table 4.4: Adjusted Natural Gas Usage for Eagle Hall using linear September weather adjusted data

Month	Ccf (Sept)	BTU	MMBtu
July	434	44268000	44.3
August	552	56304000	56.3
September	485	49470000	49.5
October	4924	502250488	502.3
November	7992	815192668	815.2
December	8976	915576953	915.6
January	9813	1000917816	1000.9
February	8006	816613619	816.6
March	7066	720754174	720.8
April	4352	443896884	443.9
May	711	72522000	72.5
June	450	45900000	45.9
Annual	53761	5483666601	5484

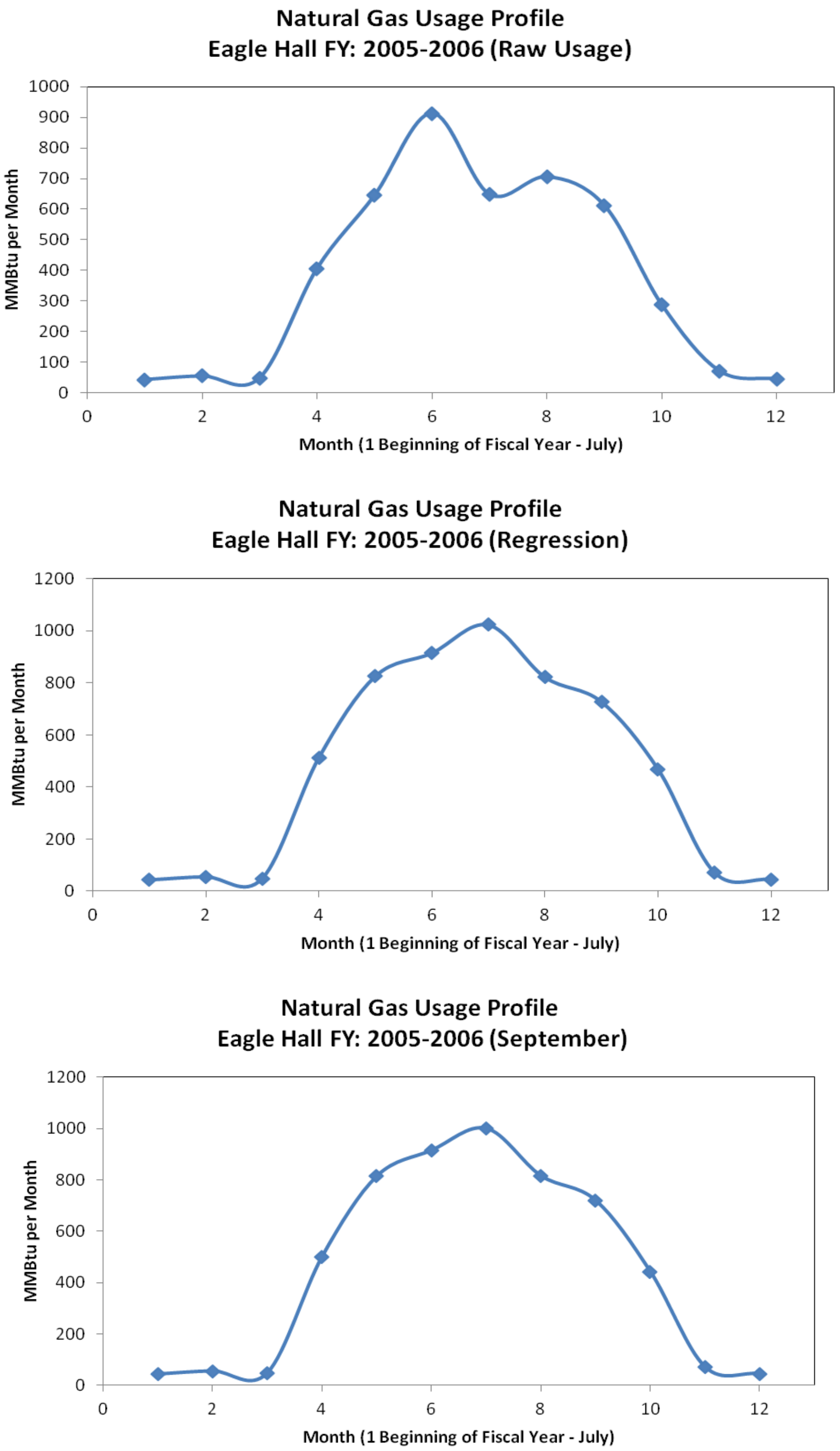


Figure 4.2: Raw and Weather Adjusted Natural Gas Usage Profiles for Eagle Hall using both regression and September non-weather dependent adjustment methods.

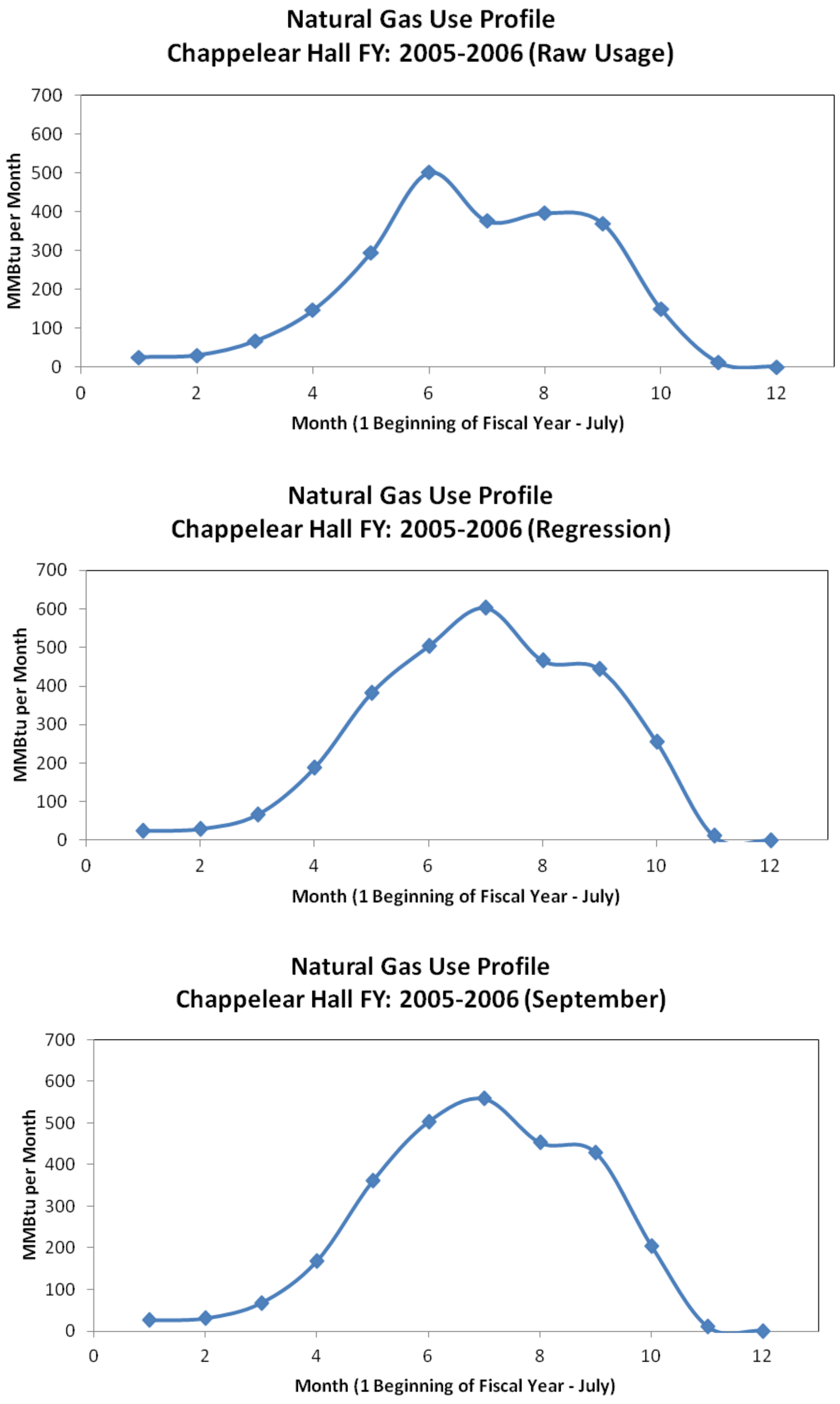


Figure 4.3: Raw and Weather Adjusted Natural Gas Usage Profiles for Chappelear Hall using both regression and September non-weather dependent adjustment methods.

Actual natural gas consumption for Eagle Hall during the 2005-2006 fiscal year begins the school year at 49.5 MMBtu in September, and peaks at 912 MMBtu in December. Consumption dips rather substantially in January to 648 MMBtu, before rising back to 705 MMBtu in February. After that point, consumption decreases quickly until the end of the school year, dropping to 287 MMBtu in April. However, in order to compare Eagle Hall to other buildings or to itself in other years, this data has to be weather-adjusted. The weather adjustment process alters the profile rather substantially. The weather adjusted profiles are very similar to one another, both peaking in January at around 1000 MMBtu, with December and February being both markedly less. This is due to the effects of weather-adjusting the data. In 2005, December saw 932 heating degree days, very close to the 30 year average of 935 HDD. Conversely, January 2006 only saw 673 HDD, with the 30 year average being 1070. This resulted in the adjustment of the data affecting January's consumption value much more than December, and shifting the peak. A similar phenomenon occurs in the data for Chappelear Hall, in which the raw consumption values peak in December at 502 MMBtu and January consumption being substantially less at 376 MMBtu. However, the weather adjustment of the data shifts the peak to January, with a new consumption value of 603 MMBtu, while December remains relatively unaffected at a new value of 503 MMBtu. Overall Eagle Hall uses almost twice the natural gas of Chappelear Hall, with the weather-adjusted annual total being about 5500 MMBtu, compared to Chappelear Hall at just under 3000 MMBtu. However, Eagle Hall has 240 student rooms as compared to Chappelear Hall's 103. Despite the differences in magnitude, the overall trends of natural gas consumption between the two dorms are very similar.

The next step in this project was to generate the percentage breakdown of natural gas consumption by end use. Natural gas is only used for heating and hot water in the residence halls that utilize this fuel source and in the month of September none of the residence halls are heated, so any natural gas usage can be attributed to hot water. For this reason, the Btu value for hot water is the September usage value multiplied by the number of months in the school year. The heating value used for these percentage breakdowns are from the normalized natural gas consumption prior to the addition of the non-weather dependent values for each month. The normalized values were used for fairer comparison between different years, although only the 2005-2006 fiscal year was analyzed for the purposes of this project. *Figure 4.4* shows the percentage breakdown by end use for natural gas consumption in Eagle Hall, and *Figure 4.5* shows the same information for Chappelear Hall.

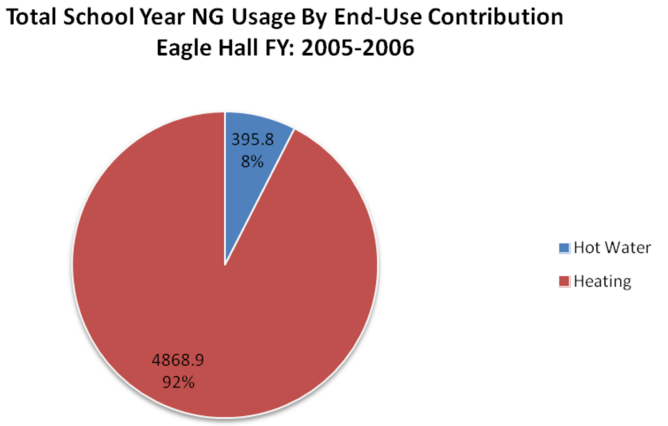


Figure 4.4: Natural Gas Usage breakdown by end use contribution for Eagle Hall fiscal year 2005-2006.

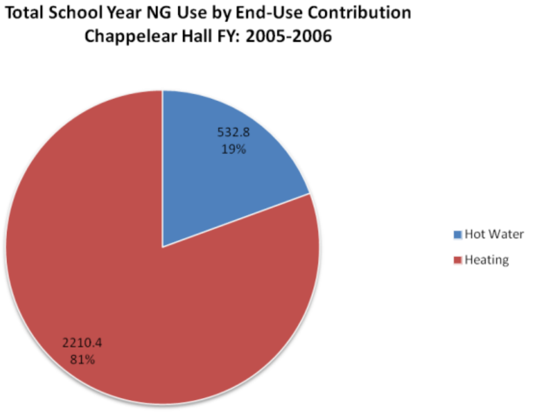


Figure 4.5: Natural Gas usage breakdown by end use contribution for Chappelear Hall fiscal year 2005-2006.

While the natural gas consumption trends for Eagle and Chappelear Hall are similar, the end use breakdowns differ quite significantly. In Eagle Hall, hot water accounts for 8% of natural gas consumption, while in Chappelear Hall, it accounts for 19%. Likewise, heating in Eagle Hall consumes 92% of natural gas, while in Chappelear, it is responsible for 81% of consumption.

Steam

The process for generating steam load profiles and end use percentage breakdowns was essentially the same as that for natural gas. As with the natural gas dorms, steam is only used in the steam using residence halls for hot water and heating. Unlike the two natural gas using dormitories, the steam using dorms are air conditioned, however Converse Hall does not use a steam chiller[9] for air conditioning, and Potomac Hall receives preconditioned chilled water from the Waste Recovery Facility on the East Campus. Currently chilled water use is not metered at the building level for any of the buildings on the east campus, including Potomac Hall, and it is not accounted for in this analysis. As with the natural gas dormitories, steam usage has been weather-adjusted to allow fair comparisons with the same buildings in subsequent years and with other buildings on the JMU campus.

Figures 4.6 and *4.7* display the raw and adjusted steam usage profiles using both the linear regression analysis and September non-weather dependent data methods for Potomac and Converse Halls respectively. Actual steam consumption for Potomac Hall at the beginning of the school year in September is 373 MMBtu, peaking in January at 1216 MMBtu, and decreasing to 585 MMBtu in April. As with the natural gas dormitories, weather adjustment of the data alters the steam usage data, but in the case of Potomac Hall the peak remains in January, increasing to a

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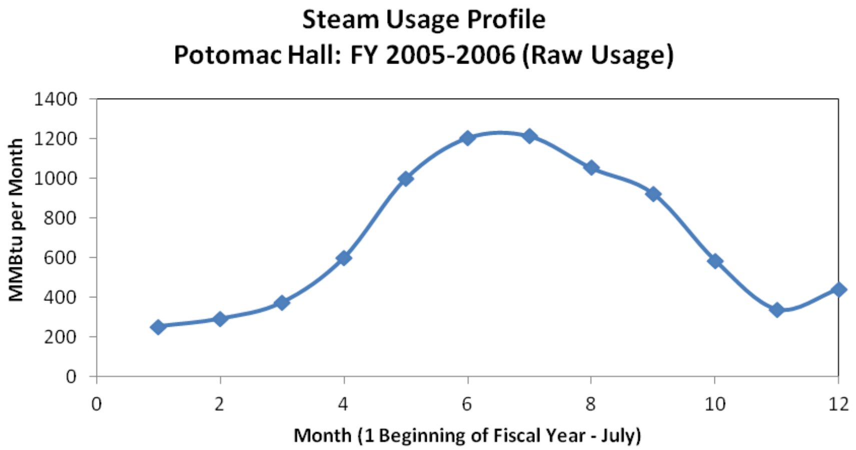
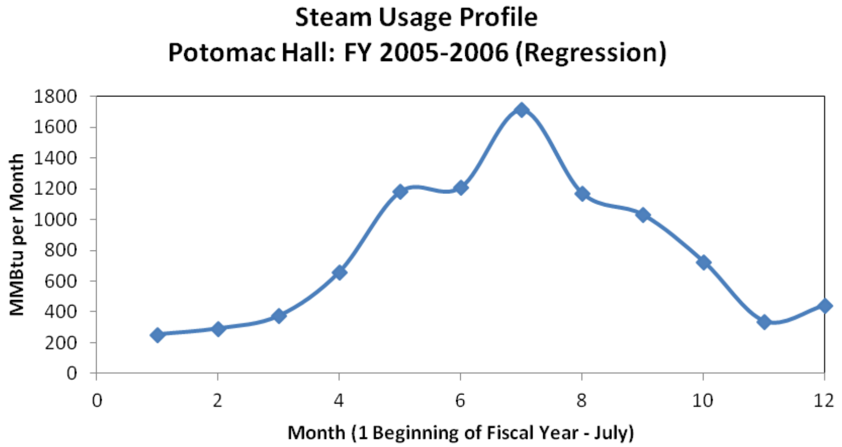
[9] A steam chiller is a type of adsorption chiller. Adsorption chillers use heat instead of mechanical energy to drive the refrigeration cycle and a steam chiller is what is known as an indirect fired adsorption chiller; instead of the machinery directly burning natural gas or some other fuel as the heat source, a secondary system provides heat through hot water, steam, or waste heat. (Piper, 1999)Adsorption chillers primarily use lithium bromide, a salt that is highly corrosive to steel in the presence of oxygen, as the heat adsorbent for the chilling process. (Piper, 1999)

new usage value of around 1750 MMBtu. Chappelear Hall’s load profile is much different than that of the other residence halls analyzed in this project. Rather than usage starting low, increasing to a peak during the winter, and decreasing again until the end of the year, Chappelear’s usage oscillates from a September usage of 171 MMBtu to a small peak of 251 MMBtu in October, decreases down to a low of 168 MMBtu in December, before reaching the peak for the year of 295 MMBtu in January. The weather adjustment of the data does not alter Chappelear’s load profile considerably; the only substantial change is the increase of January’s peak from 295 MMBtu to about 370 MMBtu. This may have to do with the large percentage of Btu usage that hot water is responsible for in Converse Hall as compared to the other residence halls. *Figures 4.8* and *4.9* show the percentage breakdown of Potomac and Converse Hall’s steam usage by end use contribution.





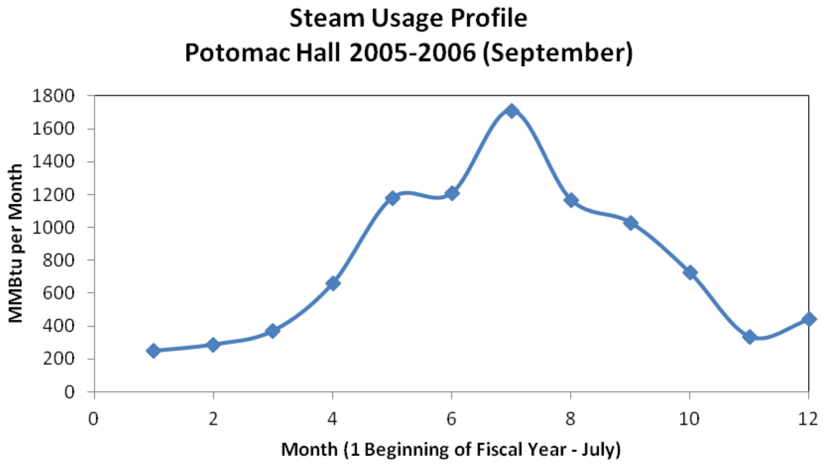
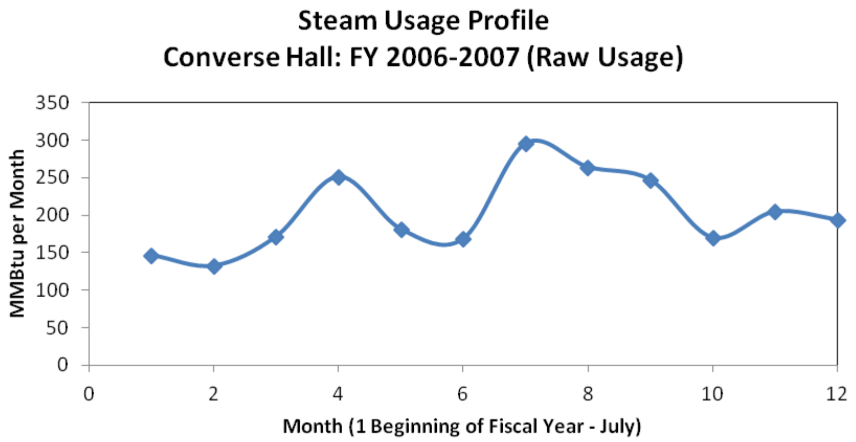
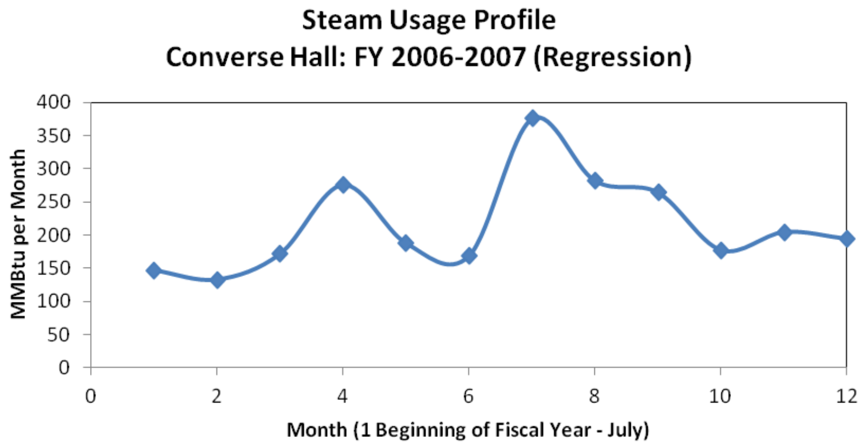


Figure 4.6: Raw and Weather Adjusted Steam Usage Profiles for Potomac Hall Fiscal Year 2005-2006.





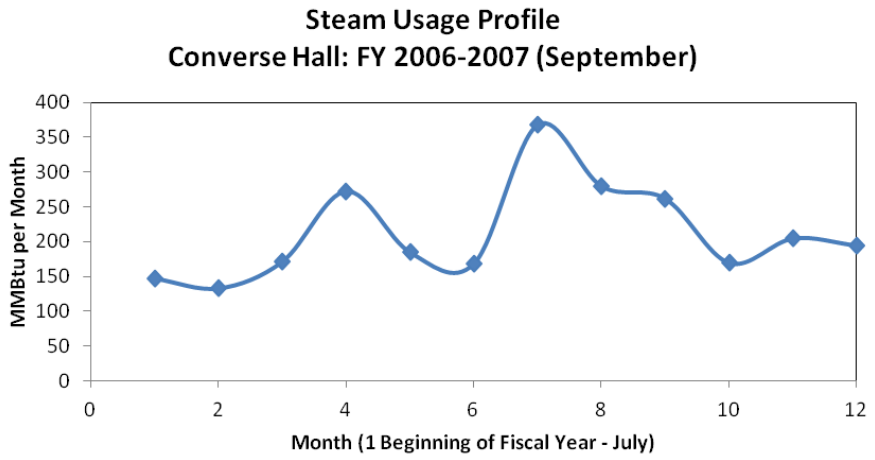


Figure 4.7: Raw and Weather Adjusted Steam Usage Profiles for Converse Hall Fiscal Year 2006-2007.

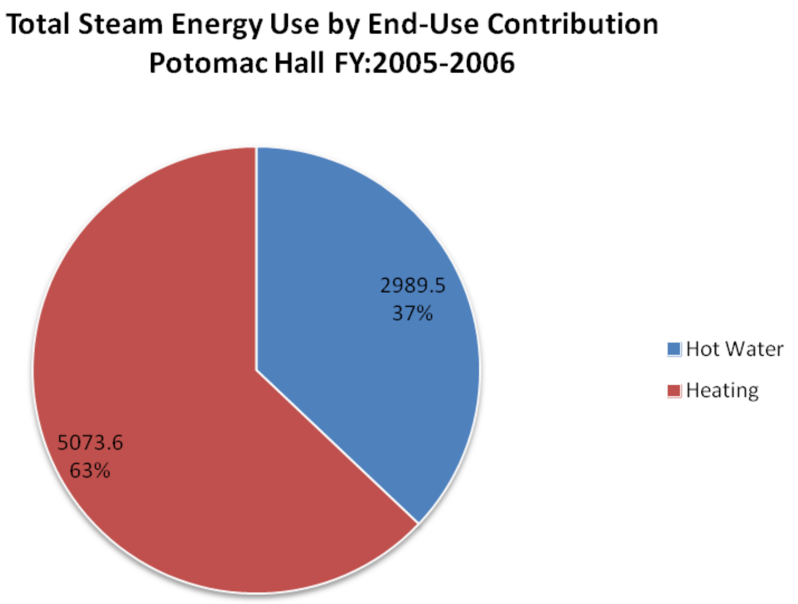


Figure 4.8: Total Steam Energy Usage of Potomac Hall by End use contribution for fiscal year 2005-2006

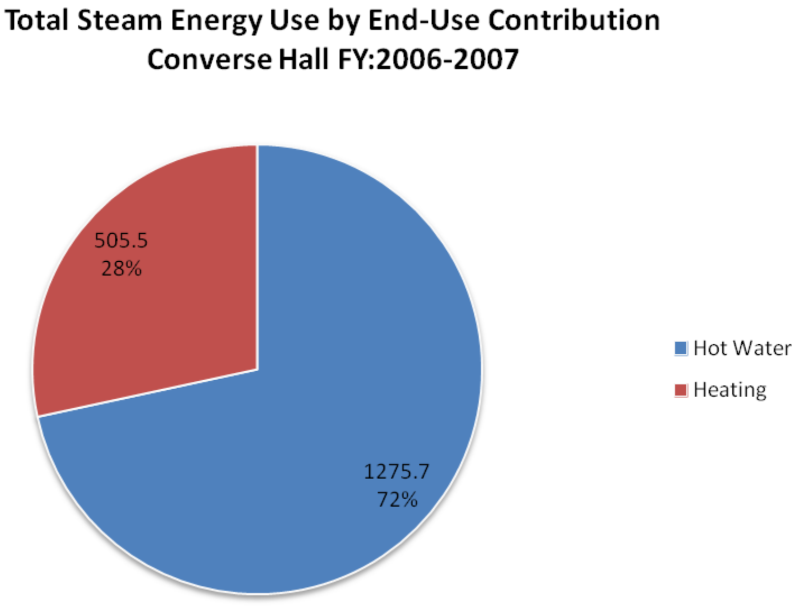


Figure 4.9: Total Steam Energy usage of Converse Hall by End use contribution for fiscal year 2006-2007.

Potomac Hall’s steam usage is similar to that of the natural gas usage in Chappelear Hall. Hot water is responsible for 37% of Potomac Hall’s steam usage, while space heating makes up the other 63%. In contrast, hot water is responsible for 72% of Converse Hall’s steam usage, with space heating only making up 28% of the consumption. It is unclear at this time why this is the case, however it may explain the small effect that weather adjusting the data has on Converse Hall, nearly three-fourths of the steam usage for that residence hall is attributed to non-weather dependent sources.

Electricity

In addition to either steam or natural gas, every residence hall on the JMU campus uses electricity. Electricity consumption, as far as can be inferred from the information available on the residence halls, is not directly related to changes in weather conditions from year to year, with the natural gas or steam usage being tied to space heating operations in the buildings. As a result, the electricity data was not weather adjusted to reflect these climatic alterations. *Figure 4.10* displays the electricity usage profiles in MMBtu for each of the four dormitories, Potomac Hall, Converse Hall, Eagle Hall, and Chappelear as a function of month of the year.

In comparison to the steam or natural gas consumption of the residence halls, which can vary significantly with the heating season, electricity usage in the dorms remains relatively flat during the school year. Potomac Hall’s electricity consumption begins the school year at 322 MMBtu eq.[10] and remains flat until December, when it drops to 241 MMBtu eq., most likely due to the holiday break and absence of students during that timeframe. Following the winter break, there is a spike in electricity usage during February to 431 MMBtu eq. before dropping back down to 303 MMBtu eq. at the end of the school year. Converse Hall’s electricity usage starts the school year at 128 MMBtu eq. in September before reaching a peak for the year in October at 137

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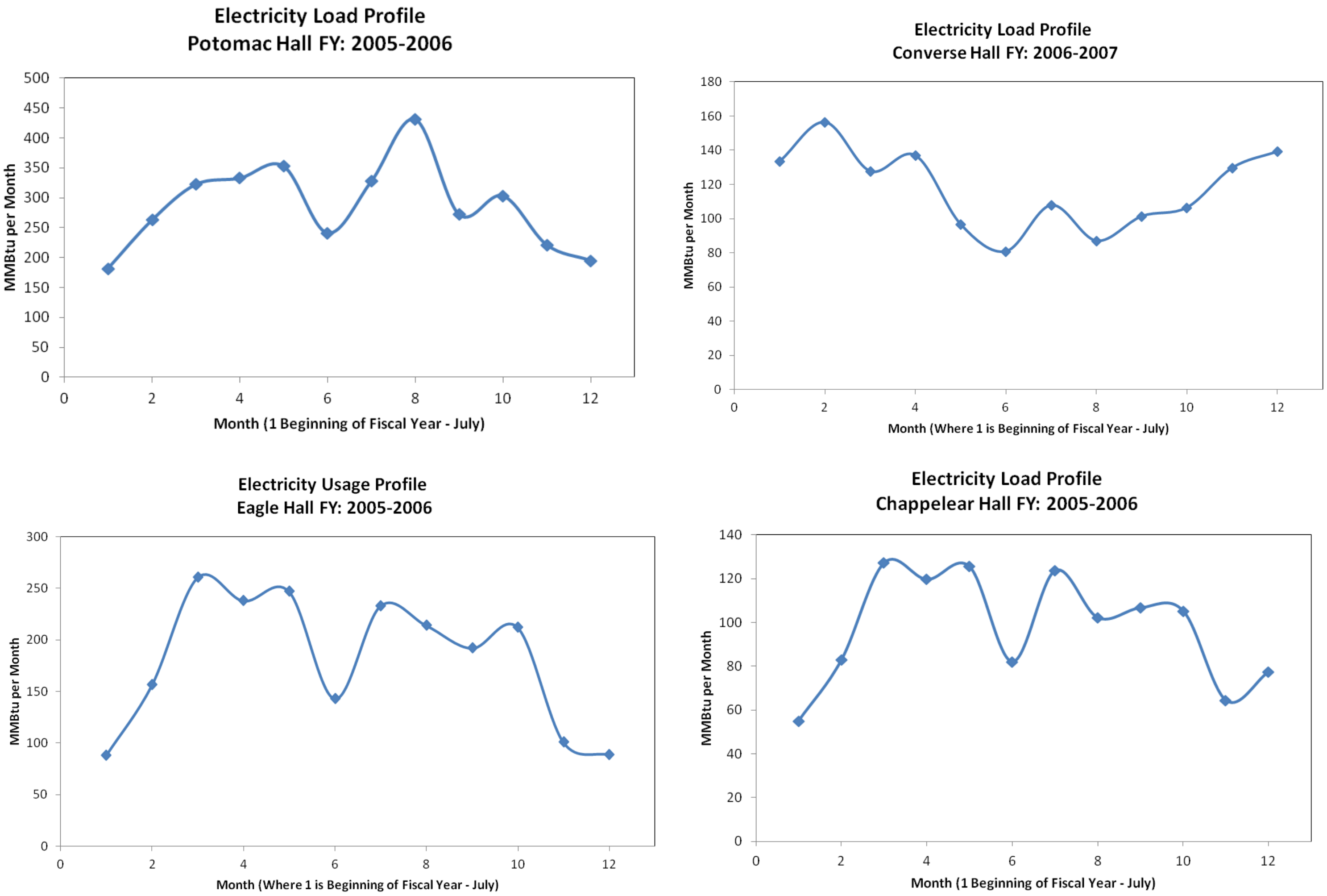
[10] MMBtu eq. denotes the Millenium Millenium Btu equivalent energy to the actual kilowatt-hour consumption of electric power, where 1 kWh is equal to 3412.142 Btu.

MMBtu eq. Similar to Potomac, usage decreases to its lowest level of 80 MMBtu eq. in December, after which consumption oscillates between just over 100 MMBtu eq. and just under 90 MMBtu eq. before finishing the year at 106 MMBtu eq. in April. Eagle Hall's consumption starts off at high of 260 MMBtu eq., remaining relatively stable at just under that level for the next 2 months before a sharp decline during December to 143 MMBtu eq. Following the winter holiday, usage increases back to 233 MMBtu eq. for January, decreasing slightly in by March to 198 MMBtu eq., before increasing to end the year at 212 MMBtu eq. in April. Chappelear Hall's consumption trend is very similar to that of Eagle Hall, just at a smaller magnitude. Consumption begins at 127 MMBtu eq. in September, decreases to 82 MMBtu eq. in December, increasing back to 125 million in January before decreasing gradually to 105 MMBtu eq. in April.


Electricity Load Profile
Potomac Hall FY: 2005-2006

Electricity Load Profile
Converse Hall FY: 2006-2007

Electricity Usage Profile
Eagle Hall FY: 2005-2006

Electricity Load Profile
Chappelear Hall FY: 2005-2006

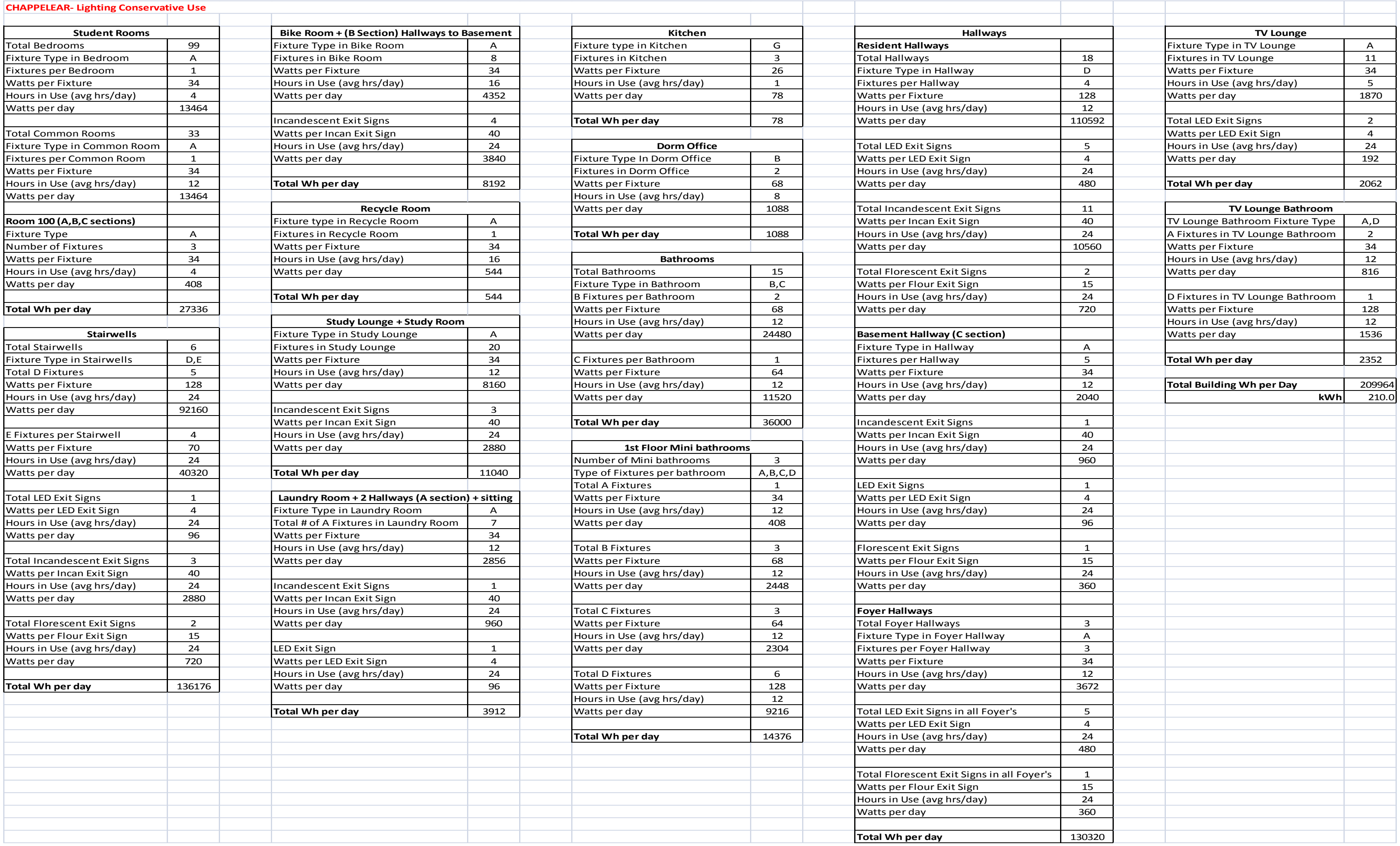
Figure 4.10: Electricity Usage Profiles for Potomac Hall FY:2005-2006, Converse Hall FY: 2006-2007, Eagle Hall FY:2005-2006, and Chappelear Hall FY:2005-2006.

Energy usage breakdowns were generated for electricity usage in the dormitories similar to those generated for natural gas and steam. These charts were generated based on three estimated levels of lighting use and contain four main end use applications; lighting, student plug loads, common-use appliances, and process power. Lighting was chosen as the independent electricity load to change based on estimated usages in the residence halls; conservative – the most energy conscientious usages, moderate – a medium or average usage of lighting, and flagrant – little or no concern for energy conservation. *Table 4.5* contains the various areas that can be found in each of the dormitories and the associated estimated light usage for that area for each of the levels of usage. Stairwells, elevator lights, foyers or residence hall entrances, and exit signs were assumed to be on 24 hours a day, seven days a week for security reasons. The rest of the dorm areas were assigned different amounts of lighting usage based on educated guesses or informal conversations with students who lived in either the residence halls of interest in this study, or residence halls in the same area as those of interest. *Table 4.6*contains an example of the spreadsheet used to estimated kilowatt-hour per day usage for each of the residence halls and levels of usage. For each room, or type of room, information on number of lights, wattage requirements of the lights, and hours in use was used to calculate a watt-hour per day consumption, with the sum of all rooms representing the total kilowatt-hour consumption per day under those parameters.

Table 4.5: Levels of Light Usage by Dormitory Area.

	Hours of Light Use		
Area of Dorm	**Conservative**	**Moderate**	**Flagrant**
Student Room	4	8	12
Stairwell	24	24	24
Recycle Room	16	20	24
Study Lounge	12	18	24
Laundry Room	12	18	24
Kitchen	1	3	5
Elevator	24	24	24
Hallways	12	18	24
Bathroom Suite	3	5	8
Bathroom Communal	12	18	24
Foyer/Entrance	24	24	24
TV Lounge	5	8	10
Common Room	12	18	24
Bike Room	16	20	24
Dorm Office	8	12	16
Exit Signs	24	24	24

Table 4.6: *Example of Lighting Load estimation spreadsheet – Chappelear Hall assuming conservative lighting use.*



CHAPPELEAR- Lighting Conservative Use

Student Rooms	
Total Bedrooms	99
Fixture Type in Bedroom	A
Fixtures per Bedroom	1
Watts per Fixture	34
Hours in Use (avg hrs/day)	4
Watts per day	13464
Total Common Rooms	33
Fixture Type in Common Room	A
Fixtures per Common Room	1
Watts per Fixture	34
Hours in Use (avg hrs/day)	12
Watts per day	13464
Room 100 (A,B,C sections)	
Fixture Type	A
Number of Fixtures	3
Watts per Fixture	34
Hours in Use (avg hrs/day)	4
Watts per day	408
Total Wh per day	27336

Stairwells	
Total Stairwells	6
Fixture Type in Stairwells	D,E
Total D Fixtures	5
Watts per Fixture	128
Hours in Use (avg hrs/day)	24
Watts per day	92160
E Fixtures per Stairwell	4
Watts per Fixture	70
Hours in Use (avg hrs/day)	24
Watts per day	40320
Total LED Exit Signs	1
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Watts per day	96
Total Incandescent Exit Signs	3
Watts per Incan Exit Sign	40
Hours in Use (avg hrs/day)	24
Watts per day	2880
Total Florescent Exit Signs	2
Watts per Flour Exit Sign	15
Hours in Use (avg hrs/day)	24
Watts per day	720
Total Wh per day	136176

Bike Room + (B Section) Hallways to Basement	
Fixture Type in Bike Room	A
Fixtures in Bike Room	8
Watts per Fixture	34
Hours in Use (avg hrs/day)	16
Watts per day	4352
Incandescent Exit Signs	4
Watts per Incan Exit Sign	40
Hours in Use (avg hrs/day)	24
Watts per day	3840
Total Wh per day	8192

Recycle Room	
Fixture type in Recycle Room	A
Fixtures in Recycle Room	1
Watts per Fixture	34
Hours in Use (avg hrs/day)	16
Watts per day	544
Total Wh per day	544

Study Lounge + Study Room	
Fixture Type in Study Lounge	A
Fixtures in Study Lounge	20
Watts per Fixture	34
Hours in Use (avg hrs/day)	12
Watts per day	8160
Incandescent Exit Signs	3
Watts per Incan Exit Sign	40
Hours in Use (avg hrs/day)	24
Watts per day	2880
Total Wh per day	11040

Laundry Room + 2 Hallways (A section) + sitting	
Fixture Type in Laundry Room	A
Total # of A Fixtures in Laundry Room	7
Watts per Fixture	34
Hours in Use (avg hrs/day)	12
Watts per day	2856
Incandescent Exit Signs	1
Watts per Incan Exit Sign	40
Hours in Use (avg hrs/day)	24
Watts per day	960
LED Exit Sign	1
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Watts per day	96
Total Wh per day	3912

Kitchen	
Fixture type in Kitchen	G
Fixtures in Kitchen	3
Watts per Fixture	26
Hours in Use (avg hrs/day)	1
Watts per day	78
Total Wh per day	78

Dorm Office	
Fixture Type In Dorm Office	B
Fixtures in Dorm Office	2
Watts per Fixture	68
Hours in Use (avg hrs/day)	8
Watts per day	1088
Total Wh per day	1088

Bathrooms	
Total Bathrooms	15
Fixture Type in Bathroom	B,C
B Fixtures per Bathroom	2
Watts per Fixture	68
Hours in Use (avg hrs/day)	12
Watts per day	24480
C Fixtures per Bathroom	1
Watts per Fixture	64
Hours in Use (avg hrs/day)	12
Watts per day	11520
Total Wh per day	36000

1st Floor Mini bathrooms	
Number of Mini bathrooms	3
Type of Fixtures per bathroom	A,B,C,D
Total A Fixtures	1
Watts per Fixture	34
Hours in Use (avg hrs/day)	12
Watts per day	408
Total B Fixtures	3
Watts per Fixture	68
Hours in Use (avg hrs/day)	12
Watts per day	2448
Total C Fixtures	3
Watts per Fixture	64
Hours in Use (avg hrs/day)	12
Watts per day	2304
Total D Fixtures	6
Watts per Fixture	128
Hours in Use (avg hrs/day)	12
Watts per day	9216
Total Wh per day	14376

Hallways	
Resident Hallways	
Total Hallways	18
Fixture Type in Hallway	D
Fixtures per Hallway	4
Watts per Fixture	128
Hours in Use (avg hrs/day)	12
Watts per day	110592
Total LED Exit Signs	5
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Watts per day	480
Total Incandescent Exit Signs	11
Watts per Incan Exit Sign	40
Hours in Use (avg hrs/day)	24
Watts per day	10560
Total Florescent Exit Signs	2
Watts per Flour Exit Sign	15
Hours in Use (avg hrs/day)	24
Watts per day	720
Basement Hallway (C section)	
Fixture Type in Hallway	A
Fixtures per Hallway	5
Watts per Fixture	34
Hours in Use (avg hrs/day)	12
Watts per day	2040
Incandescent Exit Signs	1
Watts per Incan Exit Sign	40
Hours in Use (avg hrs/day)	24
Watts per day	960
LED Exit Signs	1
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Watts per day	96
Florescent Exit Signs	1
Watts per Flour Exit Sign	15
Hours in Use (avg hrs/day)	24
Watts per day	360
Foyer Hallways	
Total Foyer Hallways	3
Fixture Type in Foyer Hallway	A
Fixtures per Foyer Hallway	3
Watts per Fixture	34
Hours in Use (avg hrs/day)	12
Watts per day	3672
Total LED Exit Signs in all Foyer's	5
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Watts per day	480
Total Florescent Exit Signs in all Foyer's	1
Watts per Flour Exit Sign	15
Hours in Use (avg hrs/day)	24
Watts per day	360
Total Wh per day	130320

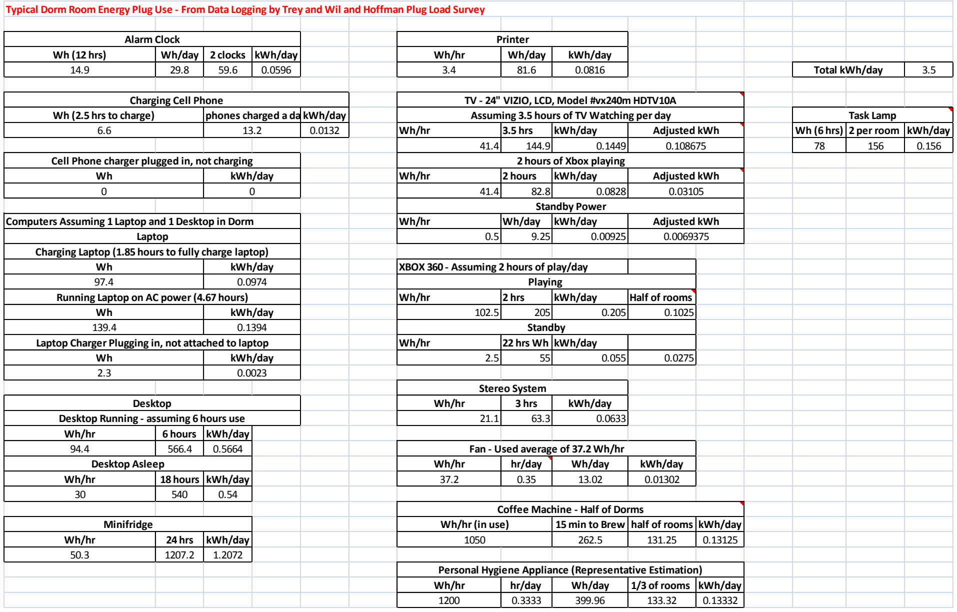
TV Lounge	
Fixture Type in TV Lounge	A
Fixtures in TV Lounge	11
Watts per Fixture	34
Hours in Use (avg hrs/day)	5
Watts per day	1870
Total LED Exit Signs	2
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Watts per day	192
Total Wh per day	2062

TV Lounge Bathroom	
TV Lounge Bathroom Fixture Type	A,D
A Fixtures in TV Lounge Bathroom	2
Watts per Fixture	34
Hours in Use (avg hrs/day)	12
Watts per day	816
D Fixtures in TV Lounge Bathroom	1
Watts per Fixture	128
Hours in Use (avg hrs/day)	12
Watts per day	1536
Total Wh per day	2352

Total Building Wh per Day	209964
kWh	210.0

Student plug loads were estimated by generating a “typical” dorm room spreadsheet which can be found in *Table 4.7*. Every dorm room in each residence hall was assumed to contain these electricity using appliances. The appliances were chosen based on a series of data logging sessions conducted by two undergraduate students who previously worked on the overarching grant that this project is a part of and from an informal plug load audit conducted in Hoffman Hall in the Spring of 2009, the results of which are found in Chapter Three of this report. A kWh per day value was generated that represents the average daily load generated by a single dorm room on campus. For the purposes of estimating student plug load in a dormitory, this value was multiplied by the number of student rooms in the residence hall and the number of school days in the semester, adjusted for an assumed five weeks of vacation during the semester – 1 week at Thanksgiving, 3 weeks during winter break, and 1 week during Spring Break.

Table 4.7: Typical Dorm Room Load Estimation Spreadsheet.



Typical Dorm Room Energy Plug Use - From Data Logging by Trey and Wil and Hoffman Plug Load Survey

Alarm Clock			
Wh (12 hrs)	Wh/day	2 clocks	kWh/day
14.9	29.8	59.6	0.0596

Charging Cell Phone		
Wh (2.5 hrs to charge)	phones charged a da	kWh/day
6.6	13.2	0.0132

Cell Phone charger plugged in, not charging	
Wh	kWh/day
0	0

Computers Assuming 1 Laptop and 1 Desktop in Dorm	
Laptop	
Charging Laptop (1.85 hours to fully charge laptop)	
Wh	kWh/day
97.4	0.0974
Running Laptop on AC power (4.67 hours)	
Wh	kWh/day
139.4	0.1394
Laptop Charger Plugging in, not attached to laptop	
Wh	kWh/day
2.3	0.0023

Desktop		
Desktop Running - assuming 6 hours use		
Wh/hr	6 hours	kWh/day
94.4	566.4	0.5664
Desktop Asleep		
Wh/hr	18 hours	kWh/day
30	540	0.54

Minifridge		
Wh/hr	24 hrs	kWh/day
50.3	1207.2	1.2072

Printer		
Wh/hr	Wh/day	kWh/day
3.4	81.6	0.0816

TV - 24" VIZIO, LCD, Model #vx240m HDTV10A			
Assuming 3.5 hours of TV Watching per day			
Wh/hr	3.5 hrs	kWh/day	Adjusted kWh
41.4	144.9	0.1449	0.108675
2 hours of Xbox playing			
Wh/hr	2 hours	kWh/day	Adjusted kWh
41.4	82.8	0.0828	0.03105
Standby Power			
Wh/hr	Wh/day	kWh/day	Adjusted kWh
0.5	9.25	0.00925	0.0069375

XBOX 360 - Assuming 2 hours of play/day			
Playing			
Wh/hr	2 hrs	kWh/day	Half of rooms
102.5	205	0.205	0.1025
Standby			
Wh/hr	22 hrs Wh	kWh/day	
2.5	55	0.055	0.0275

Stereo System		
Wh/hr	3 hrs	kWh/day
21.1	63.3	0.0633

Fan - Used average of 37.2 Wh/hr			
Wh/hr	hr/day	Wh/day	kWh/day
37.2	0.35	13.02	0.01302

Coffee Machine - Half of Dorms			
Wh/hr (in use)	15 min to Brew	half of rooms	kWh/day
1050	262.5	131.25	0.13125

Personal Hygiene Appliance (Representative Estimation)				
Wh/hr	hr/day	Wh/day	1/3 of rooms	kWh/day
1200	0.3333	399.96	133.32	0.13332

Total kWh/day	3.5

Task Lamp		
Wh (6 hrs)	2 per room	kWh/day
78	156	0.156

Common use appliance loads were estimated based on the inventory collected by the undergraduate students working on the overarching grant on washers and dryers in the dormitories, type and electrical draw of vending machines, common use televisions, and food related appliances in the dormitory such as refrigerators, ranges, and microwaves. *Table 4.8* contains an example of the common use appliances and their estimated load from Eagle Hall.

Table 4.8: Common Use Appliances Load Estimation Spreadsheet – Eagle Hall.

Eagle Hall Common Use Appliances

				wash clothes every week
# Students	448	1792	256	8.5

http://standby.lbl.gov/summary-table.html

Vending Machines - 24 hrs day/7 days week			
Type	**Number**	**kWh/day per machine**	**kWh day**
Type A	2	14.9	29.8
Type C	1	16.9	16.9
Type D	1	14.9	14.9
Non-Ref	2	2.9	5.8
Total	6		67.4

Total kWh/day	
Low	484.0
Medium	488.5
High	494.3
Average	489.0

Washers and Dryers						
W or D	**Number**	**Uses per day**	**Wh per Use**	**Standby Energy (Wh)**	**Wh per day**	**kWh/day**
Washer	14	8.5	106.2	320	17167.4	17.2
Dryer	16	7.4	3300	320	393036	393.0
Total						410.2

Washers - Maytag Neptune

Dryers - Maytag Neptune

Refrigerator						
Number	**Compressor Hours**	**Standby Hours**	**Compressor Watts**	**Standby Watts**	**Wh/day**	**kWh/day**
2	2.66664	21.33336	150	15	1439.9928	1.4

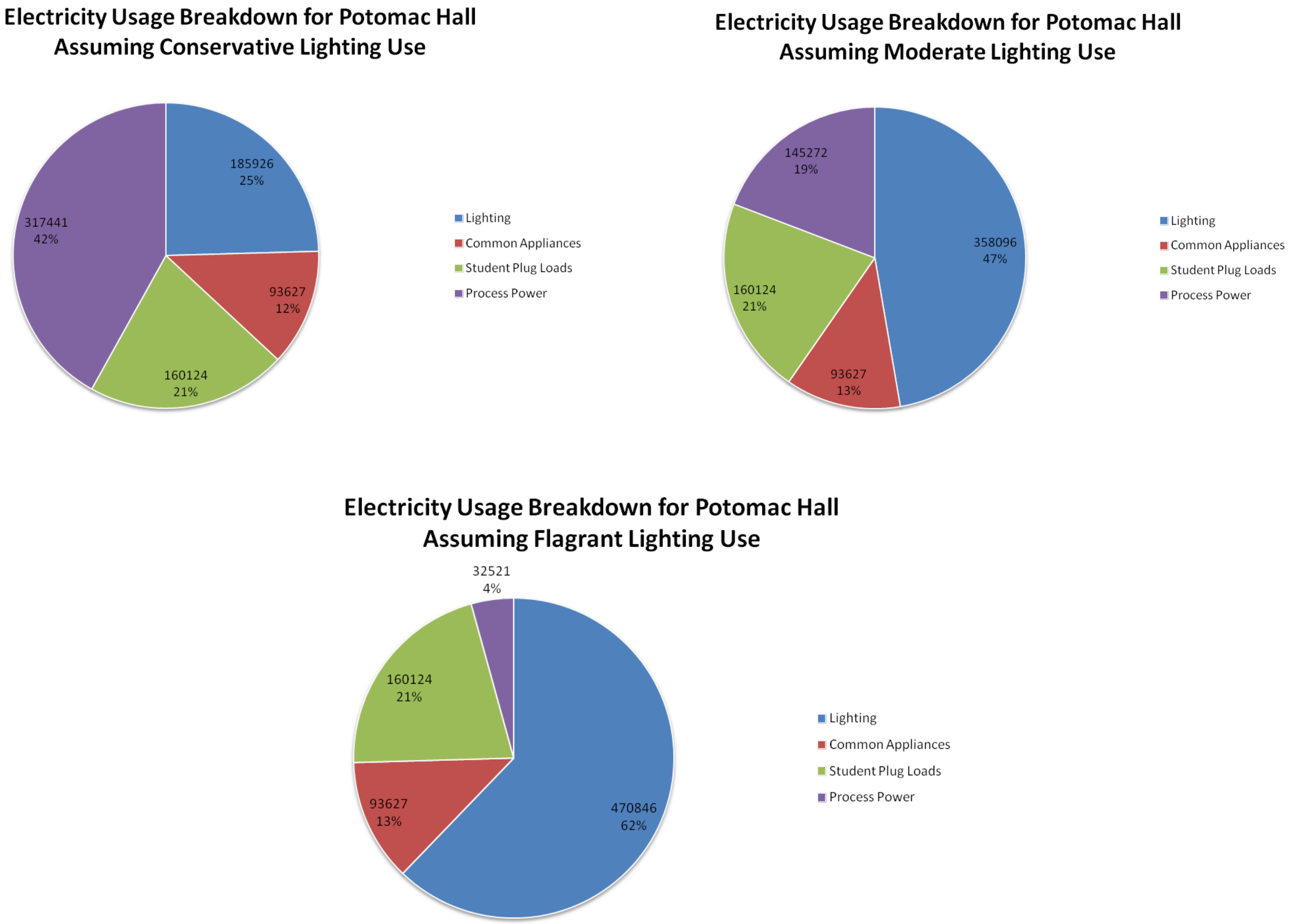
Microwave							
Level of Usage	**StandBy W**	**Usage W**	**Use hours/day**	**Standby Wh**	**Usage Wh**	**Total Wh/day**	**kWh/day**
Low	3.08	1433	1.3	70.1	1791.3	3722.6	3.7
Medium	3.08	1433	2.5	66.2	3582.5	7297.4	7.3
High	3.08	1433	4.2	61.1	5970.8	12063.8	12.1

Electric Range							
Level of Usage	**Standby W**	**Usage W**	**Use hours/day**	**Standby Wh**	**Usage Wh**	**Total Wh/day**	**kWh/day**
Low	1.13	1650	0.156	26.9	257.4	568.7	0.6
Medium	1.13	1650	0.312	26.8	514.8	1083.1	1.1
High	1.13	1650	0.52	26.5	858.0	1769.1	1.8

TV Lounge - Sony 70" Tube TV							
Level of Use	**Standby W**	**Usage W**	**Use hours/day**	**Standby Wh**	**Usage Wh**	**Total Wh/day**	**kWh/day**
Low	15	787.5	0.5	352.5	393.75	746.3	0.7
Medium	15	787.5	1	345.0	787.5	1132.5	1.1
High	15	787.5	1.5	337.5	1181.25	1518.8	1.5

With these usage estimations, percentage breakdown of electricity use by end use category charts were generated for each of the dorms under each of the lighting usage estimations. Appliance and dorm room plug loads remain the same for each of the lighting level estimations, altered only by the number of dorm rooms in each residence hall in the case of student plug loads and by the actual appliances found in each residence hall in the case of common use appliances. All charts were generated for a typical school year; any summer occupancy was not taken into consideration.

Figure 4.11 contains the breakdowns for Potomac Hall. In all three lighting usage estimations, student plug loads are estimated to account for 21% of electric energy consumption. Common use appliances account for 12% of electric energy consumption under conservative lighting conditions and 13% under moderate and flagrant conditions. Lighting accounts for 25% of consumption under conservative estimates, 47% under moderate estimates, and 62% under flagrant estimates. Process power accounts for 42%, 19%, and 4% under conservative, moderate, and flagrant lighting conditions respectively. *Figure 4.12* displays the breakdown charts for Converse Hall. In all three lighting usage estimations student plug loads are estimated to account for 17% of electric energy consumption, while common use appliances account for only 5% of electric energy consumption. Lighting accounts for 14% under conservative estimates, 20% under moderate estimates, and 26% under flagrant estimates while process power accounts for 64%, 58%, and 52% respectively under these different conditions. *Figure 4.13* displays the breakdown charts for Eagle Hall. In all three lighting usage estimations student plug loads are estimated to account for 35% of electric energy consumption, while common use appliances account for 21% of electric energy consumption. Lighting accounts for 18% under conservative estimates, 24% under moderate estimates, and 32% under flagrant estimates while process power accounts for 26%, 20%, and 12% respectively under these different conditions. *Figure 4.14* displays the breakdown charts for Chappelear Hall. In all three lighting usage estimations student plug loads are estimated to account for 30% of electric energy consumption, while common use appliances account for only 13% of electric energy consumption under conservative estimates and 12% under moderate and flagrant estimates. Lighting accounts for 17% under conservative estimates, 25% under moderate estimates, and 33% under flagrant estimates while process power accounts for 40%, 33%, and 25% respectively under these different conditions.


Electricity Usage Breakdown for Potomac Hall Assuming Conservative Lighting Use

Electricity Usage Breakdown for Potomac Hall Assuming Moderate Lighting Use

Electricity Usage Breakdown for Potomac Hall Assuming Flagrant Lighting Use

Figure 4.11: Electricity Usage Breakdowns for Potomac Hall Assuming Conservative, Moderate, and Flagrant Light Use.

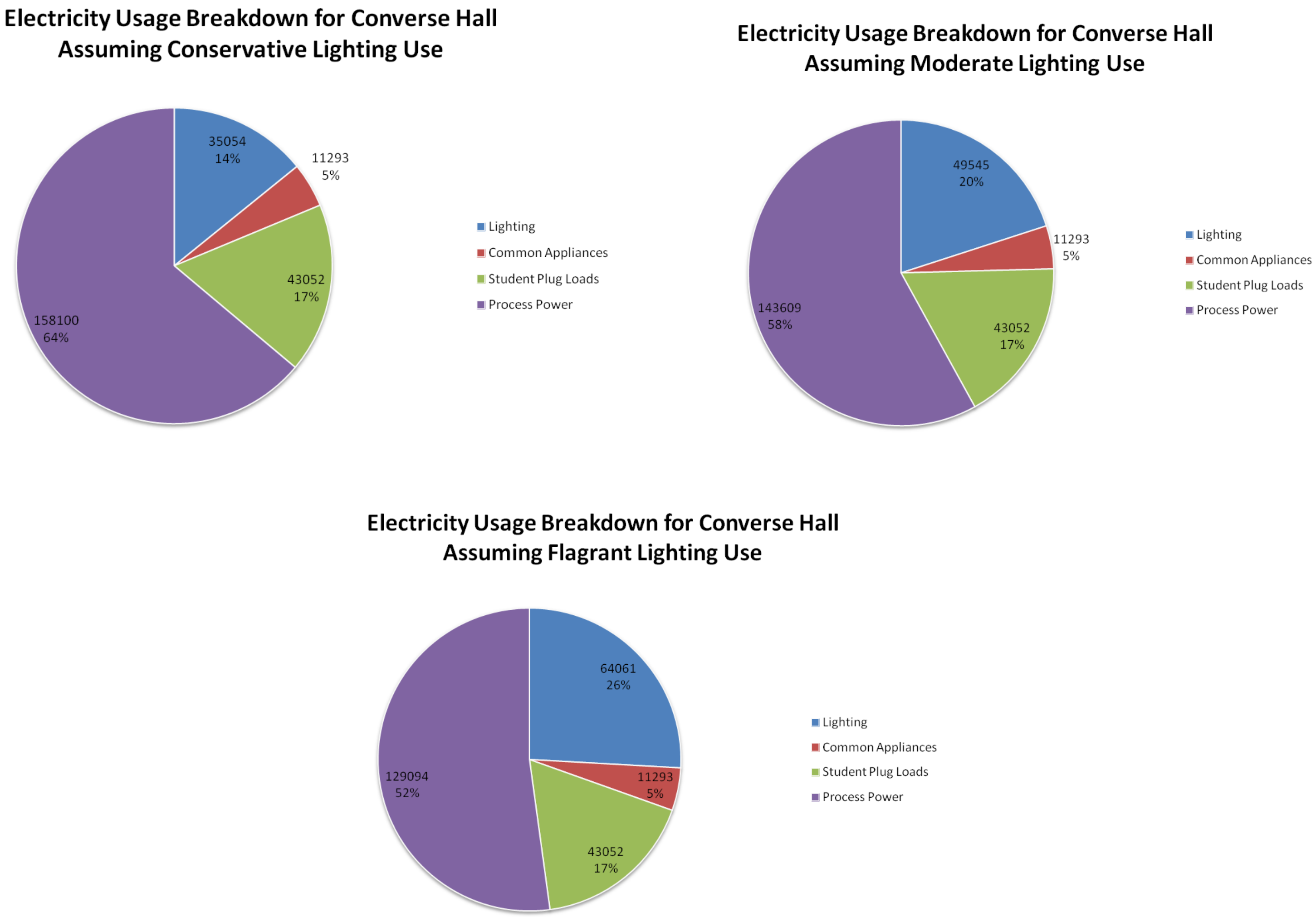


Figure 4.12: Electricity Usage Breakdowns for Converse Hall Assuming Conservative, Moderate, and Flagrant Light Use.

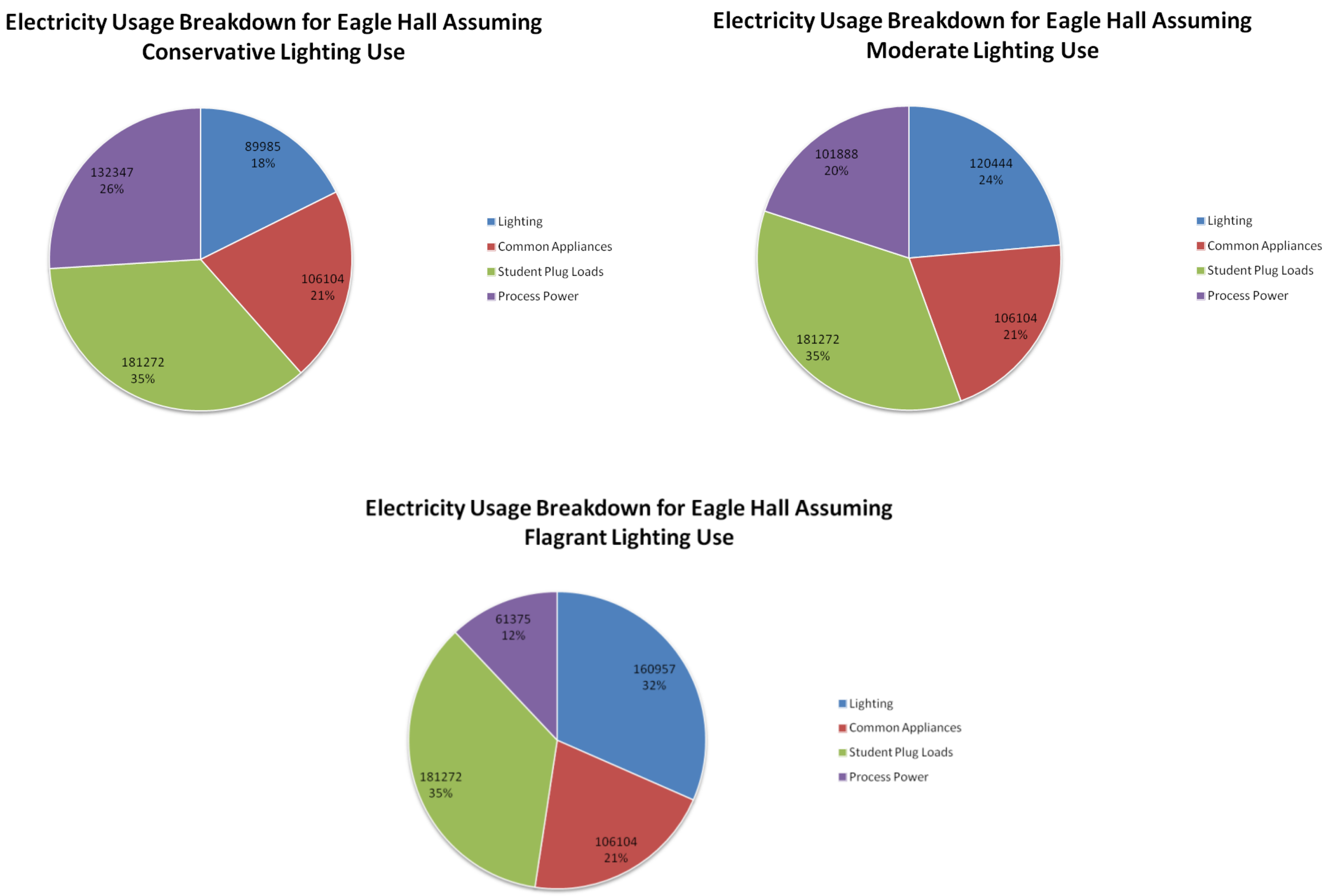


Figure 4.13: Electricity Usage Breakdowns for Eagle Hall Assuming Conservative, Moderate, and Flagrant Light Use.

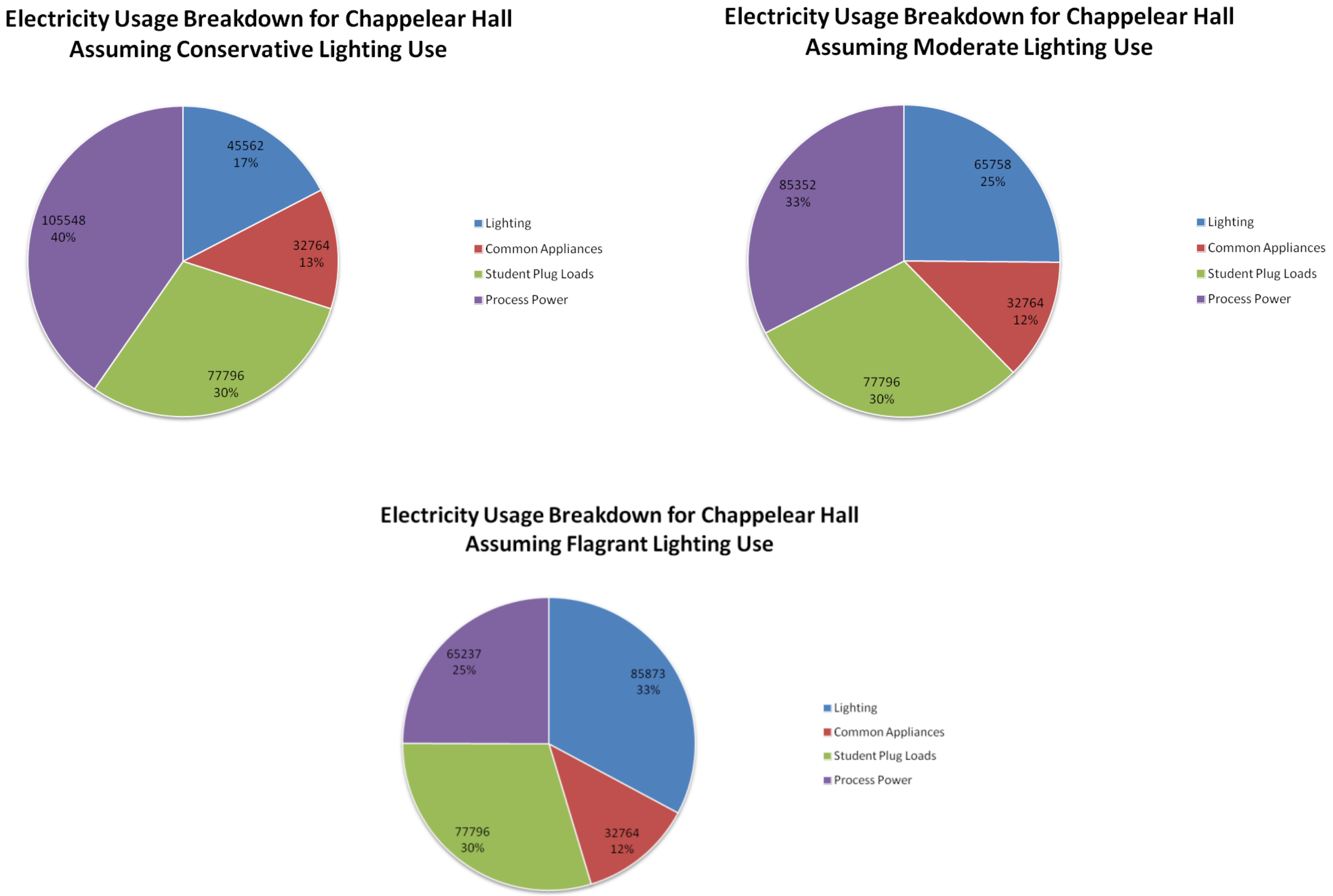


Figure 4.14: Electricity Usage Breakdowns for Chappelear Hall Assuming Conservative, Moderate, and Flagrant Light Use.

Energy Utilization Index Comparison

In order to compare energy efficiency on an even level energy usage indexes (EUI's) are utilized. An energy usage index is a measure of building efficiency by dividing the energy consumption of the building by some known building parameter, such as square footage of building area, occupancy, volume of conditioned space, etc. This allows comparison between different buildings on a similar usage basis. The EUI's of MMBtu/sq ft of building space and MMBtu/resident values were calculated for the 2005-2006 (2006-2007 in the case of Converse) school year total energy consumption values for each of the four residence halls, Potomac, Converse, Eagle, and Chappelear. The results of the MMBtu/sq ft of building space are shown in *Figure 4.15* below and the results of the MMBtu/resident calculations are show below in *Figure 4.16.*

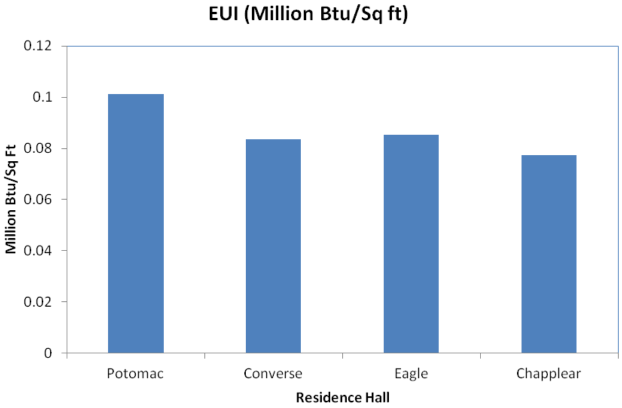


Figure 4.15: EUI (MMBtu/Sq Ft) of the four residence halls of interest: Potomac, Converse, Eagle and Chappelear.

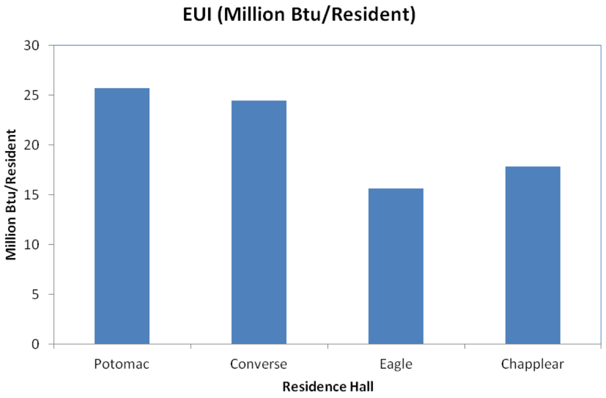


Figure 4.16: EUI (MMBtu/Resident) of the four residence halls of interest: Potomac, Converse, Eagle and Chappelear.

Potomac Hall consumes the most energy in terms of energy usage per square foot of building area at 0.101 MMBtu/Sq ft. However, Potomac Hall's consumption is understated in this analysis due to the absence of energy consumption of air conditioning from chilled water generation at the waste to steam conversion plant on campus. Converse and Eagle Halls are almost the identical in terms of MMBtu/Sq ft at 0.083 and 0.085 respectively. Chappelear is the most efficient in terms of MMBtu/Sq ft at 0.077. The EUI's of Potomac and Converse Halls, the two steam dormitories, is almost the same in terms of MMBtu/Resident at 25.7 and 24.5 respectively. Chappelear Hall is more energy efficient in terms of per resident use at 17.8 than either Potomac or Converse Hall, but less energy efficient than Eagle Hall with its EUI of 15.0 MMBtu/Resident.

Total Energy Consumption

The final step in the analysis of the energy loads experienced by these residence halls was to compile the natural gas or steam usages with the electricity usages to obtain an annual total energy use profile and energy use by end use contribution breakdown chart for each. In order to reflect values based on full occupancy and ensure fairness in comparison, the charts were generated using the September non-weather dependent adjustment values for steam or natural gas. *Figure 4.17* displays the total energy use profiles for the four residence halls, Potomac Hall, Converse Hall, Eagle Hall, and Chappelear Hall. The addition of the electricity usage figures does not alter the load profiles a great deal. This is most likely due to the fact that the electricity usage is relatively stable for the residence halls throughout the school year, so the biggest effect of adding in the electricity usage figures is an increase in the magnitude of the energy profiles. The total usage profiles of Potomac, Eagle, and Chappelear all have fairly similar trends. Usage increases steadily starting in September, except for a slight reduction during December, before peaking in January. Following January, usage decreases for the rest of the year. Converse Hall is an outlier in this set, its monthly usage seems to vary rather irregularly for some unknown reason.

In addition to the total energy usage profiles, charts showing the breakdown of energy by end use contribution of consumption charts have been generated for each of the four dorms. These charts display the energy consumption for each of the dormitories under each of the three lighting estimates with the addition of natural gas or steam data weather adjusted data using September as the non-weather dependent consumption. *Figure 4.18* displays the breakdowns of the four residence halls under conservative estimates, *Figure 4.19* displays the breakdowns under moderate estimates, and *Figure 4.20* contains this information for flagrant estimates. For the three levels of lighting estimates, space heating and hot water contribute the majority of total energy consumption in all four dormitories except for Converse Hall. Space heating is responsible for 70% of total consumption in Eagle Hall, 61% in Chappelear, 48% in Potomac, and only 19% in Converse. The next largest contributing factor in the residence halls is hot water, except for Eagle Hall. Hot water accounts for 60% of Btu consumption in Converse Hall, 28% in Potomac Hall, 15% in Chappelear, and only 8% in Eagle Hall.

Electricity usage is only responsible for between 24-31% of total energy usage in the four dormitories of interest in this project. Student Plug Loads make up less than 10% of total energy consumption in all four dorms for all levels of lighting usage estimation, ranging from 5-9% for any given residence hall. Common use appliances also make up a very small fraction of total energy usage, from 1-5% in any of the dormitories. Lighting consumption and process power consumption are the two values that change with the different lighting estimation levels. Lighting at no point reaches more than 10% of total energy usage in any of the dormitories except for Eagle Hall, in which it reaches 11% under moderate lighting usages and 15% under flagrant lighting usages. Process power in the residence halls is responsible for 10% or less of total energy consumption in the residence halls under any lighting usage conditions except for Converse Hall, where it is responsible for 20%, 17%, and 15% of energy usage under conservative, moderate, and flagrant lighting usage levels respectively. The majority of all energy loads are from the use of natural gas or steam for the generation of heat and hot water in the residence halls. *Figure 4.21* displays the percentage breakdown of total energy use for each of the dormitories by energy source, electricity and natural gas or steam. The implications of these percentages of total energy usage are discussed in Chapter 5 under conclusions and insights.

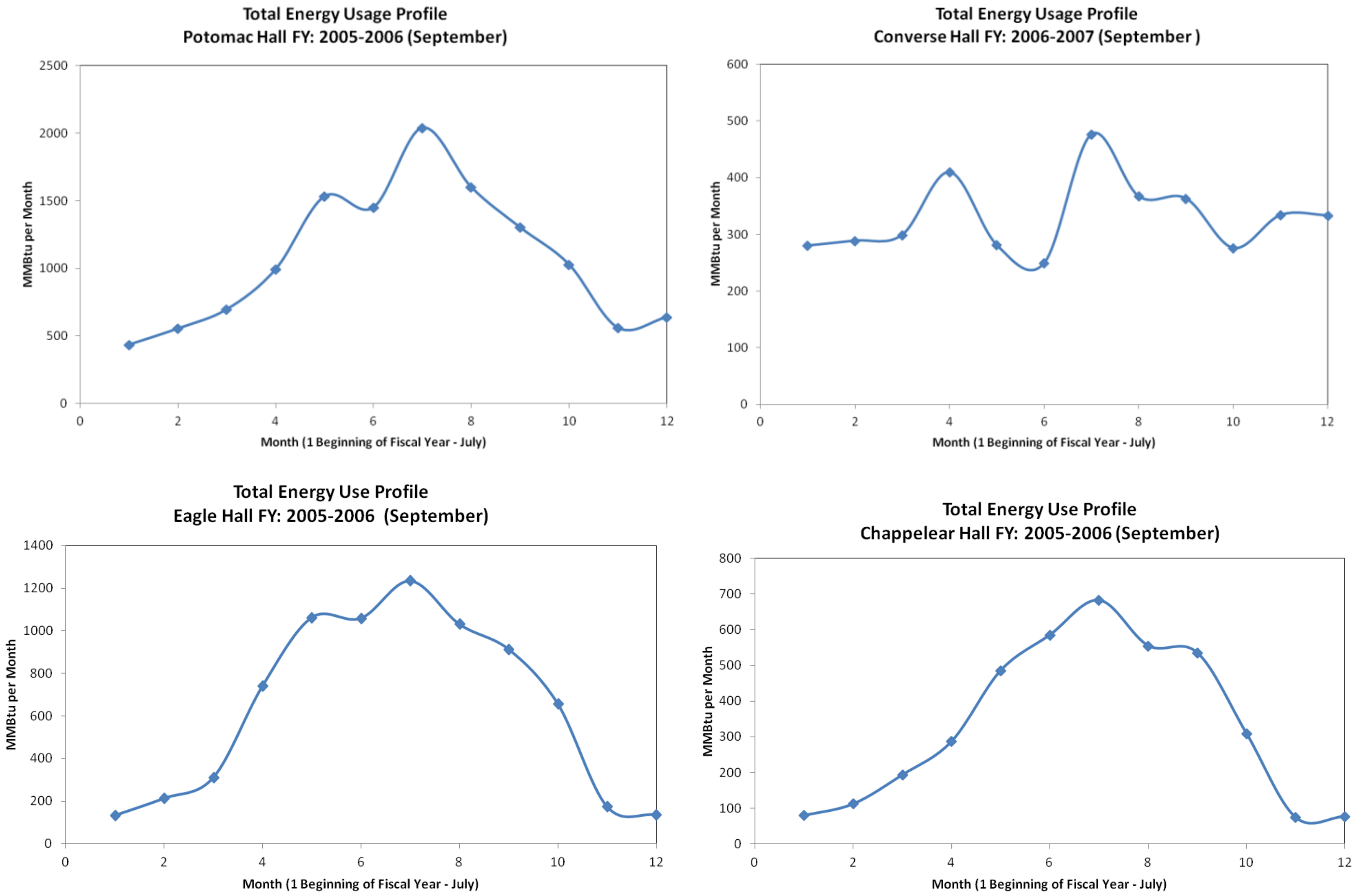
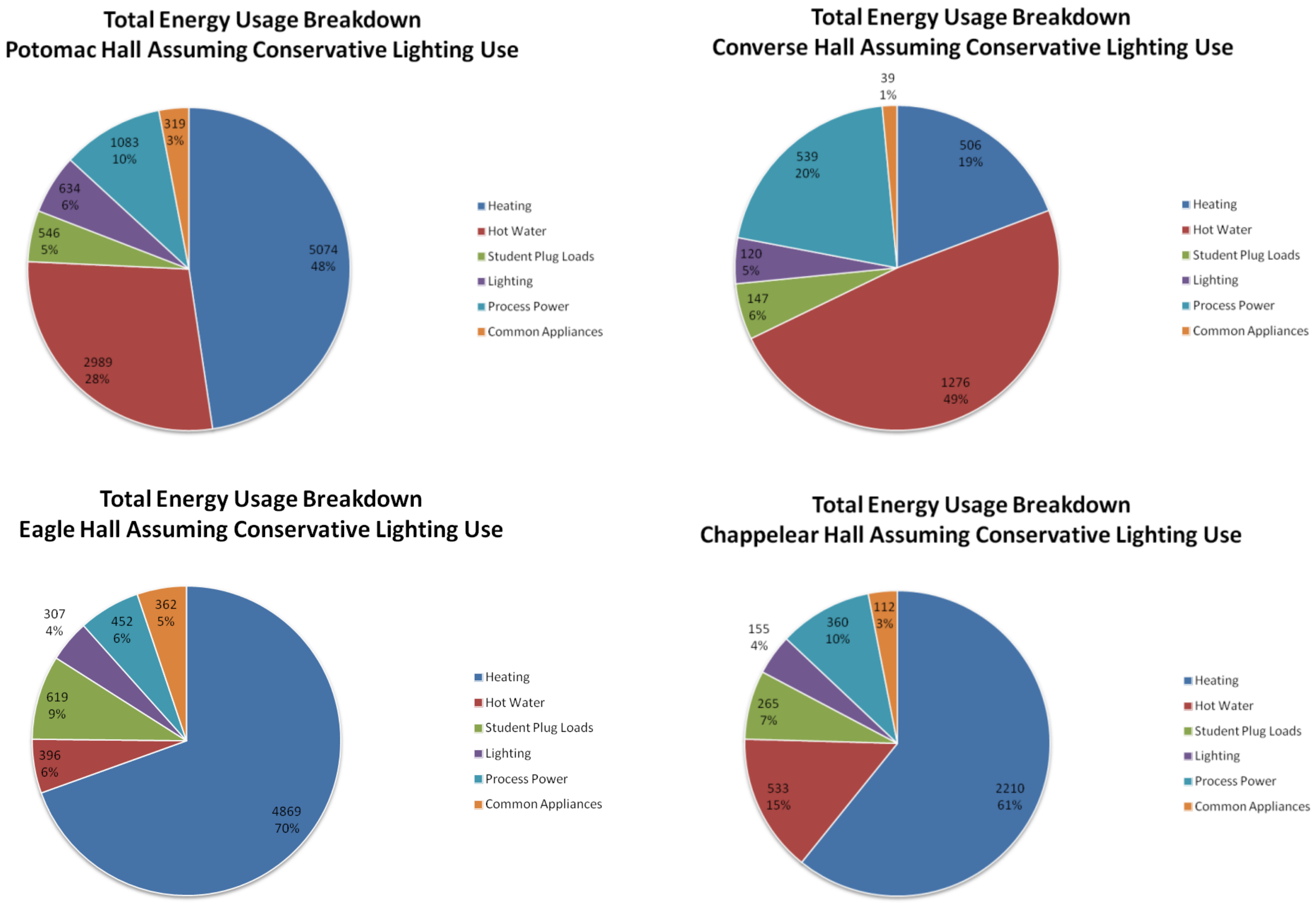


Figure 4.17: Total Energy Use Profiles for Potomac Hall, Converse Hall, Eagle Hall, and Chappelear Hall using September Non-weather dependent data.


Total Energy Usage Breakdown Potomac Hall Assuming Conservative Lighting Use

Total Energy Usage Breakdown Converse Hall Assuming Conservative Lighting Use

Total Energy Usage Breakdown Eagle Hall Assuming Conservative Lighting Use

Total Energy Usage Breakdown Chappelear Hall Assuming Conservative Lighting Use

Figure 4.18: Total Energy Usage Breakdowns for the four halls assuming conservative lighting use.

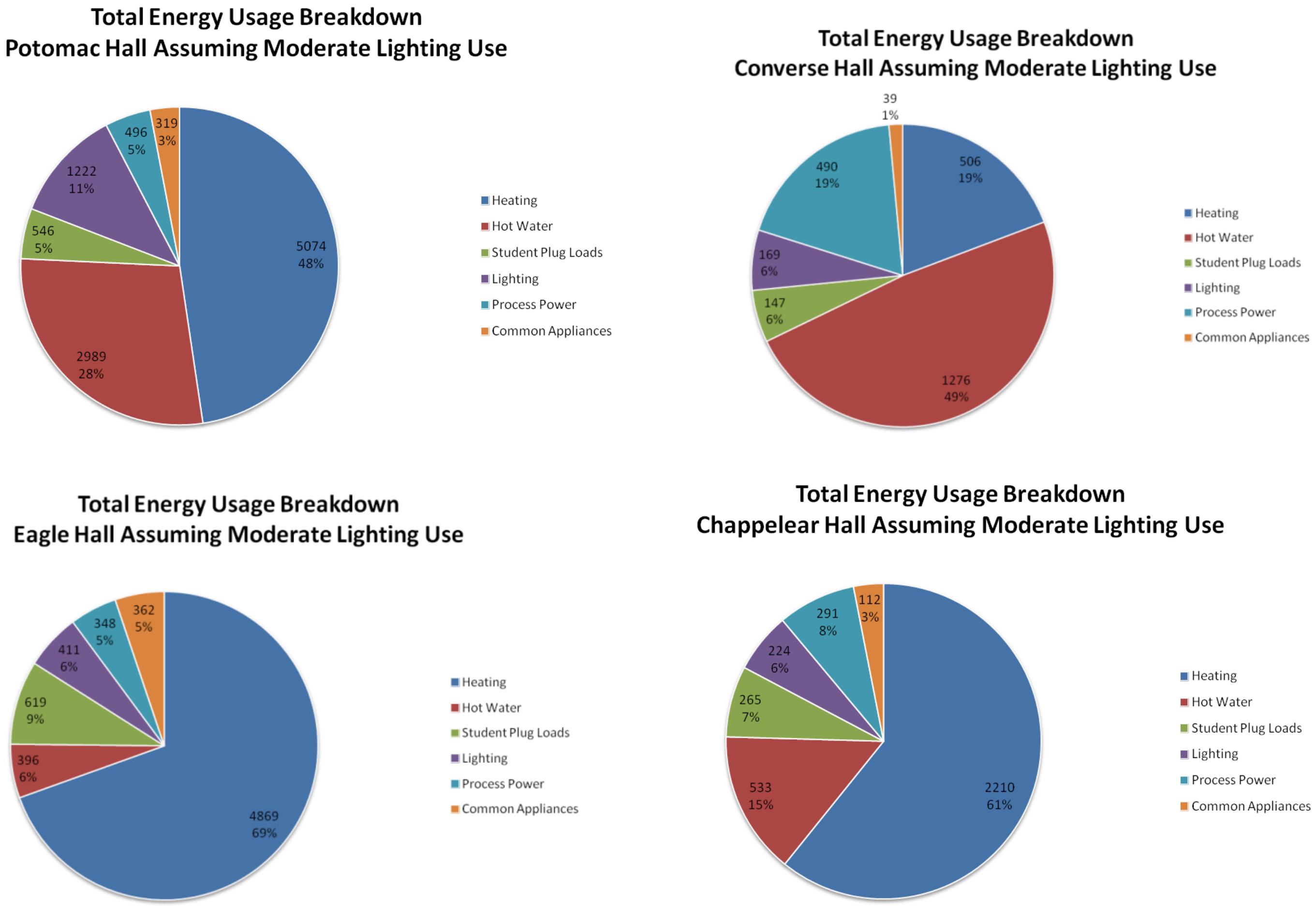
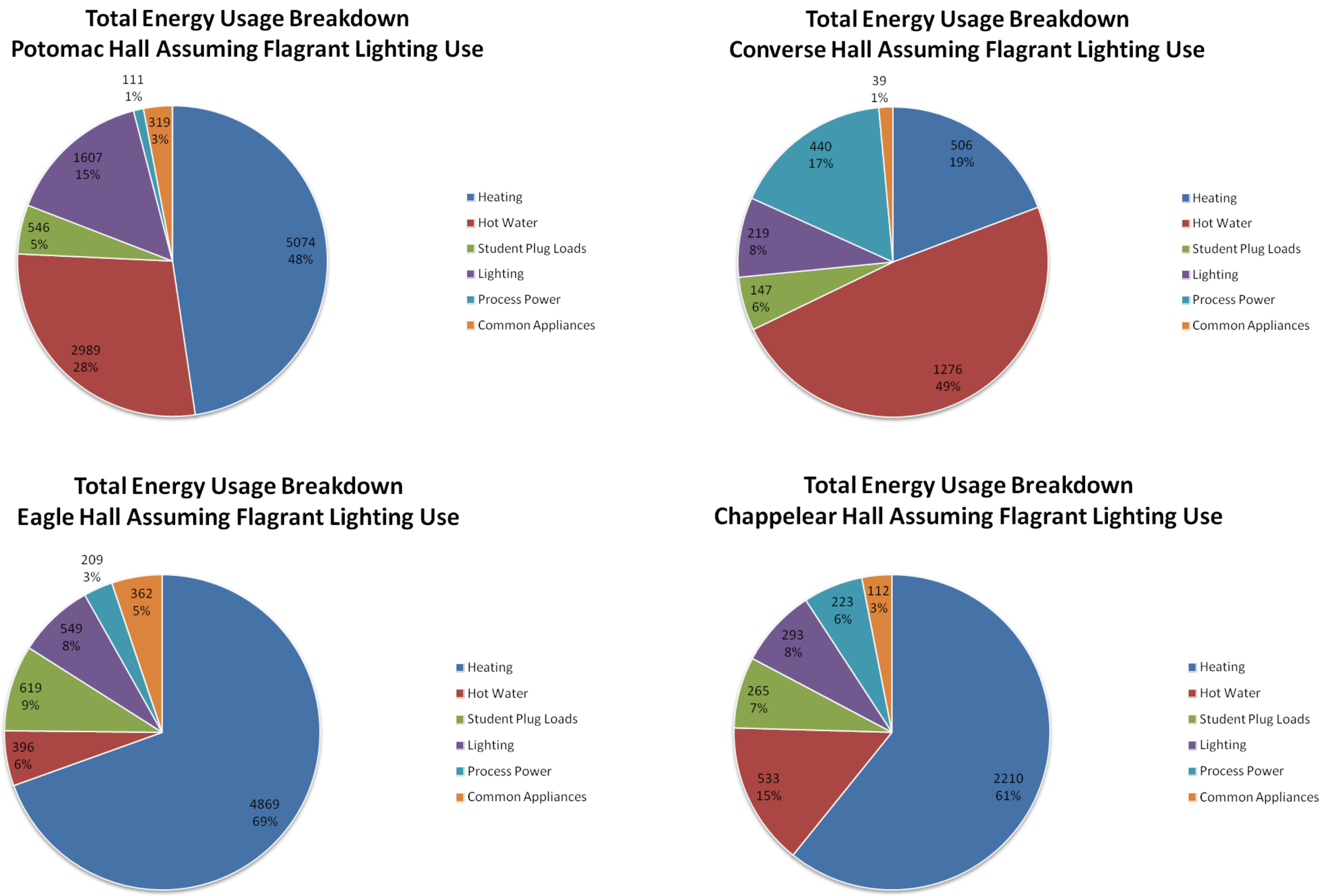


Figure 4.19: Total Energy Usage Breakdowns for the four halls assuming moderate lighting use.



Total Energy Usage Breakdown Potomac Hall Assuming Flagrant Lighting Use

Total Energy Usage Breakdown Converse Hall Assuming Flagrant Lighting Use

Total Energy Usage Breakdown Eagle Hall Assuming Flagrant Lighting Use

Total Energy Usage Breakdown Chappelear Hall Assuming Flagrant Lighting Use

Figure 4.20: Total Energy Usage Breakdowns for the four halls assuming flagrant lighting use.

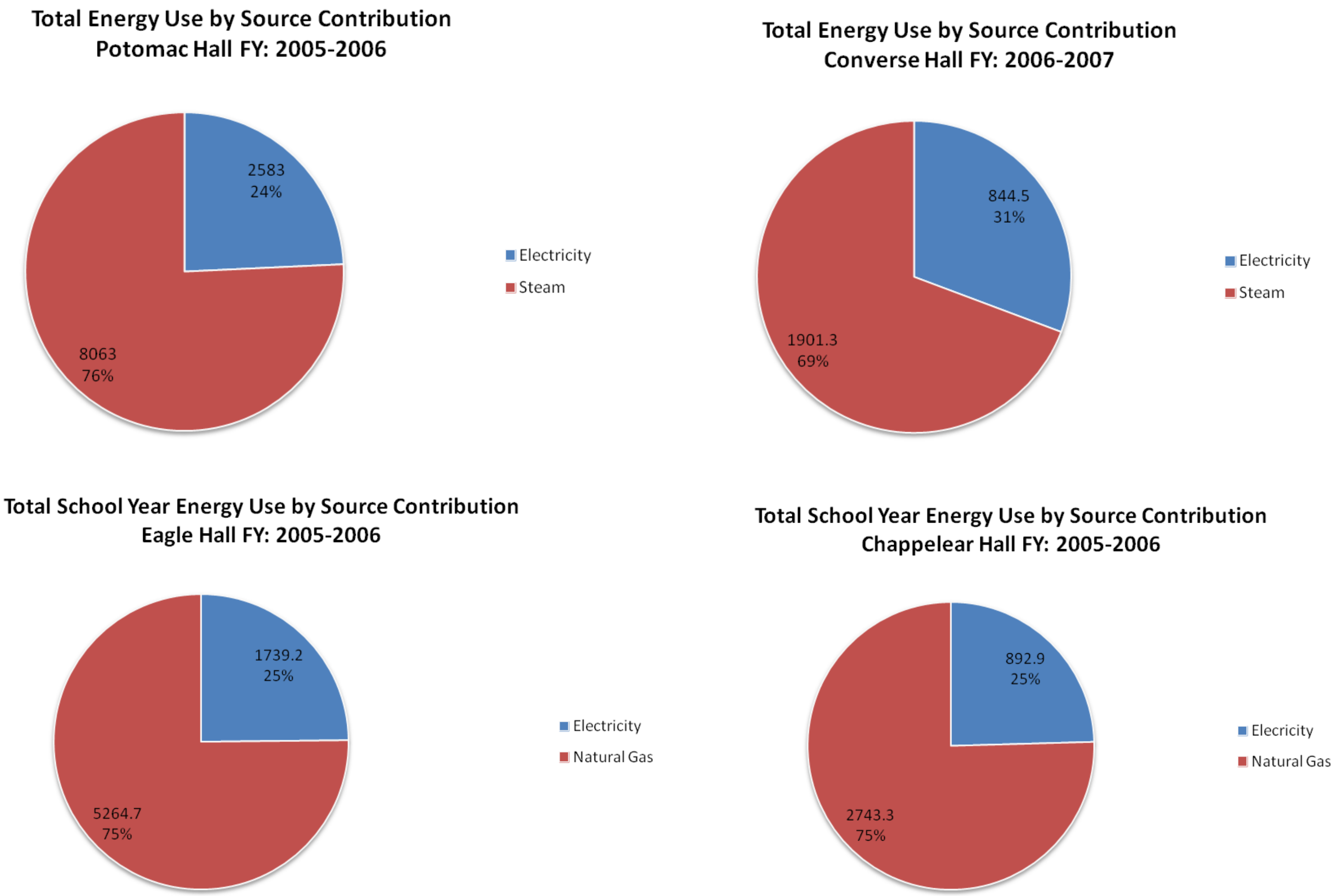


Figure 4.21: Total Energy Usage Breakdowns for the four halls by Energy Source Contribution

Chapter 5: Conclusions and Insights

Results of Data Analysis

The purpose of this project was to provide a methodology for the estimation of energy loads in university residence halls with the purpose of providing a starting point for the evaluation of energy saving options in the presence of different building construction and energy sourcing for those buildings in which detailed metering and sub-metering is not available. The two end products from this project are the total energy load profiles for the dormitories and the percentage breakdown pie charts of end use contribution to energy consumption.

The total energy load profiles generated for Potomac Hall, Converse Hall, Eagle Hall, and Chappelear Hall provide a snapshot of energy use for a given fiscal year and the weather-adjustment process allows those profiles to be compared on an even basis with other residence halls and with themselves in different fiscal years. For three of the four residence halls, energy use starts off rather low during the beginning of the school year, increases as the school year progresses further into the heating season, except for a slight reduction in December that may be attributed to the long winter break. After energy consumption peaks in January, it begins to decrease as the heating season wanes into the Spring semester until it reaches roughly the same level in April that it began the school year in September. The outlier is Converse Hall, which peaks in October and oscillates after that month. It is unclear at this point why this hall experiences such a usage trend, although the relatively small contribution of energy use that heating is responsible for may be a factor. Although present in the total energy load profiles, summer use is not really accounted for and is of little consequence due to the differing conditions from year to year on summer occupancy. The most important part of the energy consumption of these residence halls occurs during the school year. In addition to these total energy consumption profiles, the end use contribution percentage charts help to understand where this energy is being consumed.

The pie charts of total energy use help to provide insight on the major end uses of energy consumption in these halls. Although based on generous assumptions concerning use, the conservative, moderate, flagrant lighting use approach allows for the presentation of possible scenarios of consumption patterns. These charts also allow one to get an idea of where ESO’s (Energy Saving Options) will be most beneficial that may go against intuition on energy use. For example, despite the emphasis placed on lighting and the energy consumption associated with it, in none of the dorms under any of the lighting use assumptions does energy consumption of lighting account for more than 6% of total energy consumption, even under flagrant lighting conditions with assumptions of lights being left on for 24 hours a day, seven days a week. As a result, any ESO’s applied to lighting, while they may have the potential to make real energy savings, will at best only affect 6% of energy use. Additionally, student plug loads account for only 5-9% of total energy use in any of the residence halls, so any actions taken to reduce student plug loading will at best affect 9% of total consumption. The same is true for the common use appliances, such as the provision of high efficiency washers and dryers, which is 5% or less of energy consumption.

The process power in the residence halls is the unaccounted for loads, and in this model, changes with the alteration of levels of lighting use. However, even these loads account for 10% or less of energy consumption except in Converse Hall, where it is 20% of total energy use, which may benefit rather substantially from ESO’s aimed at reducing process power. Overall, electricity accounts for between 24-31% of energy consumption in these dormitories and with the variety of end uses responsible for electric energy consumption, it would most likely be necessary to implement ESO’s aimed at several of these end uses simultaneously to make a significant impact on energy consumption in the residence halls. It may be more productive if electricity is not the target of initial ESO's, but rather natural gas or steam use.

The majority of end use energy in the residence halls, based on these models, is a result of steam or natural gas use, either for heating or the generation of domestic hot water. These two end uses together account for 69-76% of total Btu consumption in the buildings, with heating responsible for 50% or more of energy usage in three of the four buildings. In order to see significant up front

identical in MMBtu per resident, at 25.7 for Potomac Hall and 24.5 for Converse Hall. Eagle Hall reductions, ESO's aimed at reducing the heating load in these buildings may be the most productive choice. Once these ESO's have been implemented, load profiles could be generated again for the buildings to evaluate the effectiveness of their implementation and determine the next most beneficial initiative to be undertaken.

The residence halls vary in terms of age, building style, individual room style, and whether or not they have air conditioning. The oldest building is Converse Hall, which was built in 1935. It has been renovated recently and air conditioning was added to the building. The other air conditioned building is Potomac Hall, which was built in 1998. In terms of Energy Utilization, these two dormitories are almost and Chappelear Hall are similar in terms of their age, built in 1970 and 1968 respectively, and neither building has air conditioning. Their EUI's in MMBtu/resident are also close, at 15.6 for Eagle Hall and 17.8 for Chappelear Hall. Both Eagle Hall and Chappelear Hall also have communal bathrooms, and are somewhat similar in terms of MMBtu/sq ft., at .085 and 0.077 MMbtu respectively. Converse Hall has suite style bathrooms, in which two dorm rooms share a single bathroom. Converse Hall's EUI in terms of MMBtu/sq ft. is closer to Eagle Hall than any other residence hall at 0.083. Potomac Hall has both communal and suite style bathrooms and has the highest EUI at 0.10 MMBtu/sq ft.

Strengths and Limitations of Methodology

The methodology of generating the load profiles is meant to provide a means of estimating energy usage in the absence of advanced metering and sub-metering for universities that are wishing to implement ESO's and increase energy sustainability without the capital available for large-scale or expensive projects. As such, the effectiveness of any ESO's implemented based on these methods of energy use estimation are going to be determined by the strength of the models and methods put forth in this document and any limitations of those initiatives will likewise be affected by the limitations of these methods. The methods of load profiling in this document are fairly strong, being based on established guidelines for the same purpose in commercial and industrial applications. They are simply the combination of available metered data, established weather-adjustment calculations, and energy conversion calculations. Therefore, the strength of the load profiles is directly related to the accuracy of the metered data and the steps taken to mitigate the inaccuracies associated with the weather adjustment of the data as described in the Weather Normalization section of Chapter Three.

The largest source of uncertainty in these profiles is the weather normalization, however any limitations of those calculations will be present in all calculations for the same buildings or set of buildings as long as the same process is carried out. Therefore, the uncertainty will be present to the same, or almost the same degree, in all buildings allowing an equal comparison between them. The more consequential uncertainty and limitations have to do with the generations of the end use contribution breakdowns of total energy use.

The generation of the total energy breakdown by end use contribution charts is comprised of the Btu consumption of heating and air-conditioning, domestic hot water, and electric loads. In the case of the JMU residence halls analyzed in this project, air-conditioning is not present in either Eagle or Chappelear Hall. Air-conditioning is provided for in Potomac Hall through chilled water produced at the waste plant on the east-side of the JMU campus and but the chilled water consumption was not available at the time of this project, so air-conditioning was not considered in this study. Converse Hall is also air-conditioned and that air-conditioning is not provided for through chilled water, and at the time of this study it was not clear how conditioned air is provided and as a result was also not accounted for in this study. For this reason, the energy consumption analysis for Potomac and Converse Hall does not take into account the energy consumption required for providing conditioned air, and as a result these analyses do not reflect cooled air generation and are "incomplete." A study of how to incorporate conditioned air into the energy profiles is currently underway.

Despite this incompleteness due to the lack of air-conditioning energy consumption, the heating and domestic hot water components of the energy breakdowns are reliable. It is known that space heating and hot water are provided for by natural gas in Eagle and Chappelear and steam in Potomac and Converse, and that during the first month of full occupancy, no buildings on the JMU campus are heated. It can be inferred that all Btu consumption during that month in either steam or natural gas is a result of domestic hot water, and assuming bathing and clothes washing habits do not change, these values can be assumed to be the baseload consumption of these energy sources. Furthermore, any additional consumption above these values can be attributed to heating, resulting in the Btu consumptions for heating and hot water. The greatest uncertainty has to do with the individual end use estimations for electricity loading.

The electricity breakdowns for the halls are a result of assumptions on equipment and usage within the halls. The lighting portion of the electricity usage is fairly complete, with only a few instances of unknowns such as the lights contained within the dorm offices in two of the dorms, which were locked at the time of the inventory. The uncertainty resides in the usage of those lights on a daily basis. An attempt at mitigation of this uncertainty was undertaken by providing for three levels of lighting usage, with the assumption that true lighting usage is most likely between any two of the usage estimations. Additionally, these different levels of lighting usage give an indication of how lighting loads can be reduced if it is assumed that they are at a higher level, and through the installation of occupancy sensors and an aggressive “Turn off the lights” campaign, can be reduced.

The student plug portion of electricity usage was based on an informal plug load audit previously conducted on Hoffman Hall in the Spring of 2009 and data collected by two undergraduate students who had previously worked on the overarching grant that this project is a part of. A “typical” dorm room energy load estimation was created due to the impractical nature of taking a complete audit of all student appliances and electronics as well as surveying each student on how long they use those appliances in a given day. The limitations are that any given dorm room may use much more or much less energy per day than the “typical” one constructed for the purposes of this project, however it is assumed that the true value lies somewhere around the calculated value.

The final calculated load, the common appliances, is one that is probably closest to the actual value. The main energy consumption of these common use appliances is more than likely as a result of the vending machines and washers and dryers in the residence halls. Through data logging experiments conducted by the two undergraduate students, it is assumed that energy consumption of these appliances is accurate. The difference of actual electricity consumption and estimated consumption based on these end uses was assumed to make up the process power of the building, or power associated with blowers, fans, and other unaccounted for loads. The accuracy of these load estimations is directly tied to the accuracy of energy consumption estimations and usage estimations, however a balance must be found between detailed inventory of the appliances and usage, and the time and resources required to conduct the analysis. Despite any uncertainties, these end use contribution breakdowns provide valuable insight into the majority of energy consumption and insight on where ESO’s will provide the most benefit.

Opportunities for Further Study

The original plan for this study was to conduct the analyses on the residence halls using the developed methodology and then to attempt to validate the findings with data collected from one or more of the residence halls from sub-metering sensors. Due to time constraints and barriers it was not possible to perform the installation or data collection of the sensors, so the first opportunity for further study with this project is the completion of that section of the project. Through the installation of a sub-metering system on a residence hall that has been analyzed by this methodology, it would be possible to determine how accurate our estimations actually were and adjust the methodology as need be to provide the most accurate tool for higher education institutions interested in energy sustainability.

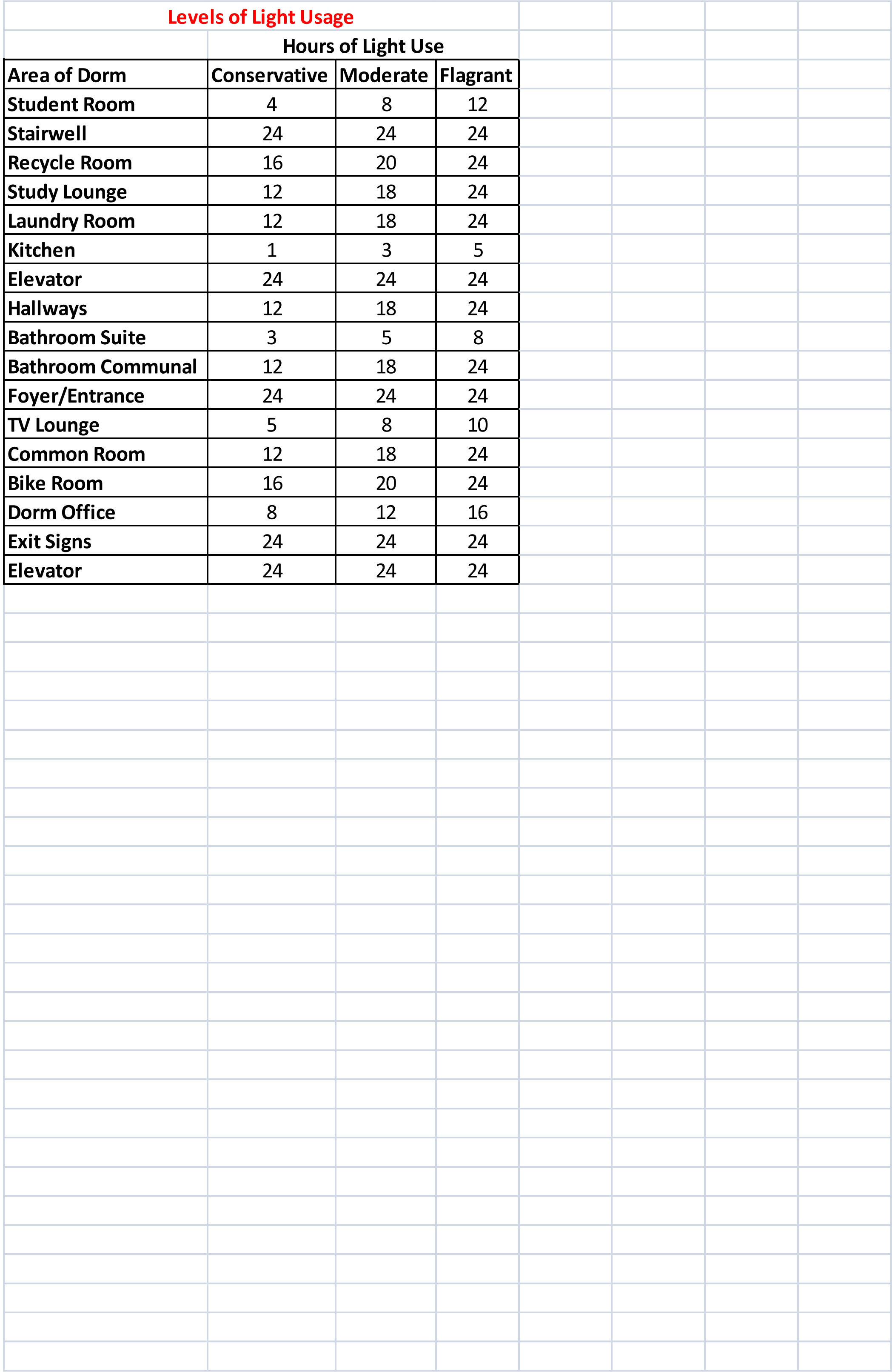
Additional further study could include the comparison of the results of this methodology with the results from the Facility Energy Decision System or FEDS software that was developed for the military in order to provide virtual load analysis of institution buildings. The combination of these two tools, if proved compatible, could allow for much quicker analysis of building loads on higher institution campuses across the country. Another opportunity for additional study might be the creation of an Excel Add-on using the methodologies developed in this project to provide an easily accessible tool that can be used quickly by anyone familiar with Microsoft Office. This would overcome the learning curve required by FEDS 6.0 and the Energy Star Profiling website to allow for quicker analysis of the data available to institutions and faster implementation of ESO’s.

Closing Remarks

As the world moves forward to a reality in which fossil fuels have a smaller role to play in society and environmental impacts become a major focus in more facets of life there will be a need for existing building stock to become more energy efficient and operate in a more environmentally sound manner. Higher education institutions may play a major role in the early stages of this transition and many have already made substantial commitments to environmental stewardship and sustainability. It is the goal of this project to ease this transition and offer a tool that can be utilized by any university, or really any person or company, who wants to make significant headway toward these objectives without the need for expensive metering or data analysis software, but instead with readily available information and means.

Appendix A: Eagle Hall Excel® Workbook

Table A-A 1: Levels of Light Usage Assumptions



Levels of Light Usage

	Hours of Light Use		
Area of Dorm	**Conservative**	**Moderate**	**Flagrant**
Student Room	4	8	12
Stairwell	24	24	24
Recycle Room	16	20	24
Study Lounge	12	18	24
Laundry Room	12	18	24
Kitchen	1	3	5
Elevator	24	24	24
Hallways	12	18	24
Bathroom Suite	3	5	8
Bathroom Communal	12	18	24
Foyer/Entrance	24	24	24
TV Lounge	5	8	10
Common Room	12	18	24
Bike Room	16	20	24
Dorm Office	8	12	16
Exit Signs	24	24	24
Elevator	24	24	24

Table A-A 2: Typical Dorm Room Energy Plug Load

Typical Dorm Room Energy Plug Use - From Data Logging by Trey and Wil and Hoffman Plug Load Survey

Total kWh/day	3.5

Alarm Clock

Wh (12 hrs)	Wh/day	2 clocks	kWh/day
14.9	29.8	59.6	0.0596

Charging Cell Phone

Wh (2.5 hrs to charge)	phones charged a da	kWh/day
6.6	13.2	0.0132

Cell Phone charger plugged in, not charging

Wh	kWh/day
0	0

Computers Assuming 1 Laptop and 1 Desktop in Dorm

Laptop

Charging Laptop (1.85 hours to fully charge laptop)	
Wh	kWh/day
97.4	0.0974
Running Laptop on AC power (4.67 hours)	
Wh	kWh/day
139.4	0.1394
Laptop Charger Plugging in, not attached to laptop	
Wh	kWh/day
2.3	0.0023

Desktop

Desktop Running - assuming 6 hours use		
Wh/hr	6 hours	kWh/day
94.4	566.4	0.5664
Desktop Asleep		
Wh/hr	18 hours	kWh/day
30	540	0.54

Minifridge

Wh/hr	24 hrs	kWh/day
50.3	1207.2	1.2072

Printer

Wh/hr	Wh/day	kWh/day
3.4	81.6	0.0816

TV - 24" VIZIO, LCD, Model #vx240m HDTV10A

Assuming 3.5 hours of TV Watching per day			
Wh/hr	3.5 hrs	kWh/day	Adjusted kWh
41.4	144.9	0.1449	0.108675
2 hours of Xbox playing			
Wh/hr	2 hours	kWh/day	Adjusted kWh
41.4	82.8	0.0828	0.03105
Standby Power			
Wh/hr	Wh/day	kWh/day	Adjusted kWh
0.5	9.25	0.00925	0.0069375

XBOX 360 - Assuming 2 hours of play/day

Playing			
Wh/hr	2 hrs	kWh/day	Half of rooms
102.5	205	0.205	0.1025
Standby			
Wh/hr	22 hrs Wh	kWh/day	
2.5	55	0.055	0.0275

Stereo System

Wh/hr	3 hrs	kWh/day
21.1	63.3	0.0633

Fan - Used average of 37.2 Wh/hr

Wh/hr	hr/day	Wh/day	kWh/day
37.2	0.35	13.02	0.01302

Coffee Machine - Half of Dorms

Wh/hr (in use)		15 min to Brew	half of rooms	kWh/day
1050		262.5	131.25	0.13125

Personal Hygiene Appliance (Representative Estimation)

Wh/hr	hr/day	Wh/day	1/3 of rooms	kWh/day
1200	0.3333	399.96	133.32	0.13332

Task Lamp

Wh (6 hrs)	2 per room	kWh/day
78	156	0.156

Table A-A 3: Common Use Appliance Loads for Eagle Hall

Eagle Hall Common Use Appliances

						wash clothes every week		
Vending Machines - 24 hrs day/7 days week				# Students	448	1792	256	8.5
Type	**Number**	**kWh/day per machine**	**kWh day**				1.142857	7.437501
Type A	2	14.9	29.8		http://standby.lbl.gov/summary-table.html		**Total kWh/day**	
Type C	1	16.9	16.9				**Low**	484.0
Type D	1	14.9	14.9				**Medium**	488.5
Non-Ref	2	2.9	5.8				**High**	494.3
Total	6		67.4				**Average**	489.0

Washers and Dryers

W or D	**Number**	**Uses per day**	**Wh per Use**	**Standby Energy (Wh)**	**Wh per day**	**kWh/day**
Washer	14	8.5	106.2	320	17167.4	17.2
Dryer	16	7.4	3300	320	393036	393.0
Total						410.2

Washers - Maytag Neptune

Dryers - Maytag Neptune

Refrigerator

Number	**Compressor Hours**	**Standby Hours**	**Compressor Watts**	**Standby Watts**	**Wh/day**	**kWh/day**
2	2.66664	21.33336	150	15	1439.9928	1.4

Microwave

Level of Usage	**StandBy W**	**Usage W**	**Use hours/day**	**Standby Wh**	**Usage Wh**	**Total Wh/day**	**kWh/day**
Low	3.08	1433	1.3	70.1	1791.3	3722.6	3.7
Medium	3.08	1433	2.5	66.2	3582.5	7297.4	7.3
High	3.08	1433	4.2	61.1	5970.8	12063.8	12.1

Electric Range

Level of Usage	**Standby W**	**Usage W**	**Use hours/day**	**Standby Wh**	**Usage Wh**	**Total Wh/day**	**kWh/day**
Low	1.13	1650	0.156	26.9	257.4	568.7	0.6
Medium	1.13	1650	0.312	26.8	514.8	1083.1	1.1
High	1.13	1650	0.52	26.5	858.0	1769.1	1.8

TV Lounge - Sony 70" Tube TV

Level of Use	**Standby W**	**Usage W**	**Use hours/day**	**Standby Wh**	**Usage Wh**	**Total Wh/day**	**kWh/day**
Low	15	787.5	0.5	352.5	393.75	746.3	0.7
Medium	15	787.5	1	345.0	787.5	1132.5	1.1
High	15	787.5	1.5	337.5	1181.25	1518.8	1.5

Table A-A 4: Conservative Lighting Loads for Eagle Hall

EAGLE HALL Conservative Light Use. Highest Level of Conservation - Based on Data from Blackboard Site

Student Rooms		**Study Lounge**		**Hallways**		**Bathrooms**		**Entrance Room + TV Lounge**	
# of Rooms	240	Fixture Type	B,E	**Resident Hallways**		**Total Bathrooms**	16	Fixture Type in TV Lounge	D,E
Fixture Type	E	# of B Fixtures	24	# of Hallways	30	Fixture Type in Bathroom	C	Total # D Fixtures in TV Lounge	10
Fixtures per Room	1	Watts per Fixture	68	Fixture Type	E	# of C Fixtures per Bathroom	5	Watts per Fixture	128
Total Fixtures	240	Hours in Use (avg hrs/day)	12	Fixtures per Hallway	3	Total Fixtures	80	Hours in Use (avg hrs/day)	5
Watts per Fixture	70	Wh per day	19584	Total Fixtures	90	Watts per Fixture	64	Wh per day	6400
Hours in Use (avg hrs/day)	4			Watts per Fixture	70	Hours in Use (avg hrs/day)	12		
Wh per day	67200	# of E Fixtures	3	Hours in Use (avg hrs/day)	12	Wh per day	61440	Total # E Fixtures in TV Lounge	9
		Watts per Fixture	70	Wh per day	75600			Watts per Fixture	70
Total Wh per day	67200	Hours in Use (avg hrs/day)	12			**Basement Bathrooms**		Hours in Use (avg hrs/day)	5
		Wh per day	2520	Total LED Exit Signs	2	Type of Fixture	C	Wh per day	3150
Stairwells				Watts per LED Exit Sign	4	# of C Fixtures	2		
# of Stairwells	2	**Total Wh per day**	22104	Hours in Use (avg hrs/day)	24	Watts per Fixture	64	LED Exit Signs	3
Fixture Type	C			Wh per day	192	Hours in Use (avg hrs/day)	12	Watts per LED Exit Sign	4
Fixtures per Stairwell	18	**Laundry Room**				Wh per day	1536	Hours in Use (avg hrs/day)	24
Total Fixtures	36	Fixture Type	E	**Wing Connecting Hallways 2nd-8th floors**				Wh per day	288
Watts per Fixture	64	Total # of E Fixtures	8	# of Connecting Hallways	7	**TV Lounge Bathroom**			
Hours in Use (avg hrs/day)	24	Watts per Fixture	70	Fixture Type	E	Fixture Type	C	**Total Wh per day**	9838
Wh per day	55296	Hours in Use (avg hrs/day)	12	# of E Fixtures per Connecting Hallway	8	Total # C Fixtures	1		
		Wh per day	6720	Total Fixtures	56	Watts per Fixture	64		
Total LED Exit Signs	2			Watts per Fixture	70	Hours in Use (avg hrs/day)	12	**Total Wh per day of Building**	414676
Watts per LED Exit Sign	4	**Total Wh per day**	6720	Hours in Use (avg hrs/day)	24	Wh per day	768	**kWh**	414.7
Hours in Use (avg hrs/day)	24			Wh per day	94080				
Wh per day	192	**Kitchen**				**Total Wh per day**	63744		
		Fixture type	D,E	Total LED Exit Signs in all Foyer's	14				
Total Wh per day	55488	# of D Fixtures	2	Watts per LED Exit Sign	4	**Dorm Office**			
		Watts per Fixture	128	Hours in Use (avg hrs/day)	24	Fixture Type in Dorm Office			
Recycle Room		Hours in Use (avg hrs/day)	1	Wh per day	1344	Fixtures in Dorm Office			
Fixture type	E,F	Wh per day	256			Total Fixtures			
# of E Fixtures	3			**Basement Hallway**		Watts per Fixture			
Watts per Fixture	70	# of E Fixtures	1	Fixtures in basement Hallways	E	Hours in Use (avg hrs/day)			
Hours in Use (avg hrs/day)	16	Watts per Fixture	70	# of E Fixtures in Basement Hallways	13	Wh per day			
Wh per day	3360	Hours in Use (avg hrs/day)	1	Total Fixtures	13				
		Wh per day	70	Watts per Fixture	70	**Total Wh per day**			
# of F Fixtures	1			Hours in Use (avg hrs/day)	12				
Watts per Fixture	112	**Total Wh per day**	326	Wh per day	10920				
Hours in Use (avg hrs/day)	16								
Wh per day	1792	**Elevator**		LED Exit Signs	3				
		Number of Elevators	2	Watts per LED Exit Sign	4				
Incandescent Exit Sign	1	Lights in Elevator	LED (9)	Hours in Use (avg hrs/day)	12				
Watts per Fixture	40	Total Fixtures	18	Wh per day	144				
Hours in Use (avg hrs/day)	24	Watts per Fixture	2						
Wh per day	960	Hours in Use (avg hrs/day)	24	**Total Wh per day**	182280				
		Wh per day	864						
Total Wh per day	6112	**Total Wh per day**	864						

Table A-A 5: Moderate Lighting Loads for Eagle Hall

Student Rooms	
# of Rooms	240
Fixture Type	E
Fixtures per Room	1
Total Fixtures	240
Watts per Fixture	70
Hours in Use (avg hrs/day)	8
Wh per day	134400
Total Wh per day	134400

Stairwells	
# of Stairwells	2
Fixture Type	C
Fixtures per Stairwell	18
Total Fixtures	36
Watts per Fixture	64
Hours in Use (avg hrs/day)	24
Wh per day	55296
Total LED Exit Signs	2
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Wh per day	192
Total Wh per day	55488

Recycle Room	
Fixture type	E,F
# of E Fixtures	3
Watts per Fixture	70
Hours in Use (avg hrs/day)	20
Wh per day	4200
# of F Fixtures	1
Watts per Fixture	112
Hours in Use (avg hrs/day)	20
Wh per day	2240
Incandescent Exit Sign	1
Watts per Fixture	40
Hours in Use (avg hrs/day)	24
Wh per day	960
Total Wh per day	7400

Study Lounge	
Fixture Type	B,E
# of B Fixtures	24
Watts per Fixture	68
Hours in Use (avg hrs/day)	18
Wh per day	29376
# of E Fixtures	3
Watts per Fixture	70
Hours in Use (avg hrs/day)	18
Wh per day	3780
Total Wh per day	33156

Laundry Room	
Fixture Type	E
Total # of E Fixtures	8
Watts per Fixture	70
Hours in Use (avg hrs/day)	18
Wh per day	10080
Total Wh per day	10080

Kitchen	
Fixture type	D,E
# of D Fixtures	2
Watts per Fixture	128
Hours in Use (avg hrs/day)	3
Wh per day	768
# of E Fixtures	1
Watts per Fixture	70
Hours in Use (avg hrs/day)	3
Wh per day	210
Total Wh per day	978

Elevator	
Number of Elevators	2
Lights in Elevator	LED (9)
Total Fixtures	18
Watts per Fixture	2
Hours in Use (avg hrs/day)	24
Wh per day	864
Total Wh per day	864

Hallways	
Resident Hallways	
# of Hallways	30
Fixture Type	E
Fixtures per Hallway	3
Total Fixtures	90
Watts per Fixture	70
Hours in Use (avg hrs/day)	18
Wh per day	113400
Total LED Exit Signs	2
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Wh per day	192
Wing Connecting Hallways 2nd-8th floors	
# of Connecting Hallways	7
Fixture Type	E
# of E Fixtures per Connecting Hallway	8
Total Fixtures	56
Watts per Fixture	70
Hours in Use (avg hrs/day)	18
Wh per day	70560
Total LED Exit Signs in all Foyer's	14
Watts per LED Exit Sign	2
Hours in Use (avg hrs/day)	24
Wh per day	672
Basement Hallway	
Fixtures in basement Hallways	E
# of E Fixtures in Basement Hallways	13
Total Fixtures	13
Watts per Fixture	70
Hours in Use (avg hrs/day)	18
Wh per day	16380
LED Exit Signs	3
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Wh per day	288
Total Wh per day	201492

Bathrooms	
Total Bathrooms	16
Fixture Type in Bathroom	C
# of C Fixtures per Bathroom	5
Total Fixtures	80
Watts per Fixture	64
Hours in Use (avg hrs/day)	18
Wh per day	92160
Basement Bathrooms	
Type of Fixture	C
# of C Fixtures	2
Watts per Fixture	64
Hours in Use (avg hrs/day)	18
Wh per day	2304
TV Lounge Bathroom	
Fixture Type	C
Total # C Fixtures	1
Watts per Fixture	64
Hours in Use (avg hrs/day)	18
Wh per day	1152
Total Wh per day	95616

Dorm Office	
Fixture Type In Dorm Office	
Fixtures in Dorm Office	
Total Fixtures	
Watts per Fixture	
Hours in Use (avg hrs/day)	
Wh per day	
Total Wh per day	

Entrance Room + TV Lounge	
Fixture Type in TV Lounge	D,E
Total # D Fixtures in TV Lounge	10
Watts per Fixture	128
Hours in Use (avg hrs/day)	8
Wh per day	10240
Total # E Fixtures in TV Lounge	9
Watts per Fixture	70
Hours in Use (avg hrs/day)	8
Wh per day	5040
LED Exit Signs	3
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Wh per day	288
Total Wh per day	15568
Total Wh per day of Building	555042
kWh	555.0

Table A-A 6: Flagrant Lighting Loads for Eagle Hall

EAGLE HALL Flagrant Light Use. Little or no Concern for conservation- Based on Data from Blackboard Site

Student Rooms	
# of Rooms	240
Fixture Type	E
Fixtures per Room	1
Total Fixtures	240
Watts per Fixture	70
Hours in Use (avg hrs/day)	12
Wh per day	201600
Total Wh per day	201600

Stairwells	
# of Stairwells	2
Fixture Type	C
Fixtures per Stairwell	18
Total Fixtures	36
Watts per Fixture	64
Hours in Use (avg hrs/day)	24
Wh per day	55296
Total LED Exit Signs	2
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Wh per day	192
Total Wh per day	55488

Recycle Room	
Fixture type	E,F
# of E Fixtures	3
Watts per Fixture	70
Hours in Use (avg hrs/day)	24
Wh per day	5040
# of F Fixtures	1
Watts per Fixture	112
Hours in Use (avg hrs/day)	24
Wh per day	2688
Incandescent Exit Sign	1
Watts per Fixture	40
Hours in Use (avg hrs/day)	24
Wh per day	960
Total Wh per day	8688

Study Lounge	
Fixture Type	B,E
# of B Fixtures	24
Watts per Fixture	68
Hours in Use (avg hrs/day)	24
Wh per day	39168
# of E Fixtures	3
Watts per Fixture	70
Hours in Use (avg hrs/day)	24
Wh per day	5040
Total Wh per day	44208

Laundry Room	
Fixture Type	E
Total # of E Fixtures	8
Watts per Fixture	70
Hours in Use (avg hrs/day)	24
Wh per day	13440
Total Wh per day	13440

Kitchen	
Fixture type	D,E
# of D Fixtures	2
Watts per Fixture	128
Hours in Use (avg hrs/day)	5
Wh per day	1280
# of E Fixtures	1
Watts per Fixture	70
Hours in Use (avg hrs/day)	5
Wh per day	350
Total Wh per day	1630

Elevator	
Number of Elevators	2
Lights in Elevator	LED (9)
Total Fixtures	18
Watts per Fixture	2
Hours in Use (avg hrs/day)	24
Wh per day	864
Total Wh per day	864

Hallways	
Resident Hallways	
# of Hallways	30
Fixture Type	E
Fixtures per Hallway	3
Total Fixtures	90
Watts per Fixture	70
Hours in Use (avg hrs/day)	24
Wh per day	151200
Total LED Exit Signs	2
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Wh per day	192
Wing Connecting Hallways 2nd-8th floors	
# of Connecting Hallways	7
Fixture Type	E
# of E Fixtures per Connecting Hallway	8
Total Fixtures	56
Watts per Fixture	70
Hours in Use (avg hrs/day)	24
Wh per day	94080
Total LED Exit Signs in all Foyer's	14
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Wh per day	1344
Basement Hallway	
Fixtures in basement Hallways	E
# of E Fixtures in Basement Hallways	13
Total Fixtures	13
Watts per Fixture	70
Hours in Use (avg hrs/day)	24
Wh per day	21840
LED Exit Signs	3
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Wh per day	288
Total Wh per day	268944

Bathrooms	
Total Bathrooms	16
Fixture Type in Bathroom	C
# of C Fixtures per Bathroom	5
Total Fixtures	80
Watts per Fixture	64
Hours in Use (avg hrs/day)	24
Wh per day	122880
Basement Bathrooms	
Type of Fixture	C
# of C Fixtures	2
Watts per Fixture	64
Hours in Use (avg hrs/day)	24
Wh per day	3072
TV Lounge Bathroom	
Fixture Type	C
Total # C Fixtures	1
Watts per Fixture	64
Hours in Use (avg hrs/day)	24
Wh per day	1536
Total Wh per day	127488

Dorm Office	
Fixture Type in Dorm Office	
Fixtures in Dorm Office	
Total Fixtures	
Watts per Fixture	
Hours in Use (avg hrs/day)	
Wh per day	
Total Wh per day	

Entrance Room + TV Lounge	
Fixture Type in TV Lounge	D,E
Total # D Fixtures in TV Lounge	10
Watts per Fixture	128
Hours in Use (avg hrs/day)	10
Wh per day	12800
Total # E Fixtures in TV Lounge	9
Watts per Fixture	70
Hours in Use (avg hrs/day)	10
Wh per day	6300
LED Exit Signs	3
Watts per LED Exit Sign	4
Hours in Use (avg hrs/day)	24
Wh per day	288
Total Wh per day	19388
Total Wh per day of Building	741738
kWh	741.7

Table A-A 7: Electricity Consumption for Eagle Hall: FY 2005-2006 through 2009-2010 (Btu and kWh)

Eagle Hall Electricity Usage

Building #	44		
Sq Footage	82189		
Rooms	240	SY ~	217
Beds	448	Rooms	240

kWh (From Imputed Spreadsheet)

Month	**(05-06)**	**(06-07)**	**(07-08)**	**(08-09)**	**(09-10)**
July	25798	23402	24180	23791	19000
August	45777	43588	50110	46849	46700
September	76333	63847	68285	70608	66500
October	69700	76558	69040	75400	66900
November	72341	54450	61694	45400	47000
December	41918	40113	40000	41620	40190
January	68301	63977	62300	55190	50000
February	62712	53894	52560	56100	54000
March	56260	57110	56180	46800	50200
April	62144	58000	60490	63500	58300
May	29537	23341	23600	26400	29400
June	26000	18520	17970	14300	18500
Annual	636821	576800	586409	565958	546690

BTU (1 kWh = 3412.14163 BTU)

Month	**(05-06)**	**(06-07)**	**(07-08)**	**(08-09)**	**(09-10)**
July	88026429.77	79850938.43	82505584.61	81178261.52	64830690.97
August	156197607.4	148728429.4	170982417.1	159855423.2	159347014.1
September	260459007	217855006.7	232998091.2	240924496.2	226907418.4
October	237826271.6	261226738.9	235574258.1	257275478.9	228272275
November	246837737.7	185791111.8	210508665.7	154911230	160370656.6
December	143030152.8	136871237.2	136485665.2	142013334.6	137133972.1
January	233052685.5	218298585.1	212576423.5	188316096.6	170607081.5
February	213982225.9	183893961	179342164.1	191421145.4	184255648
March	191967088.1	194867408.5	191694116.8	159688228.3	171289509.8
April	212044129.5	197904214.5	206400447.2	216670993.5	198927857
May	100784427.3	79642797.79	80526542.47	90080539.03	100316963.9
June	88715682.38	63192862.99	61316185.09	48793625.31	63124620.16
Annual	2172923445	1968123292	2000910561	1931128853	1865383708

Student Plug Loads - "Typical"		
	3.5	kWh/room/day
	835.4	kWh/day

Common Use Appliances Loads

Total kWh/day	
Low	484.0309302
Medium	488.5064276
High	494.3450075
Avg	488.9607884

Lighting Loads

Cons	414.676	kWh/day
Moderate	555.042	kWh/day
Flagrant	741.738	kWh/day

Conservative Light Usage

Total kWh SY	509709	Lighting	89985
Sum	377362	Common Appliances	106104
		Student Plug Loads	181272
		Process Power	132347

Moderate Light Usage

Total kWh SY	509709	Lighting	120444
Sum	407821	Common Appliances	106104
		Student Plug Loads	181272
		Process Power	101888

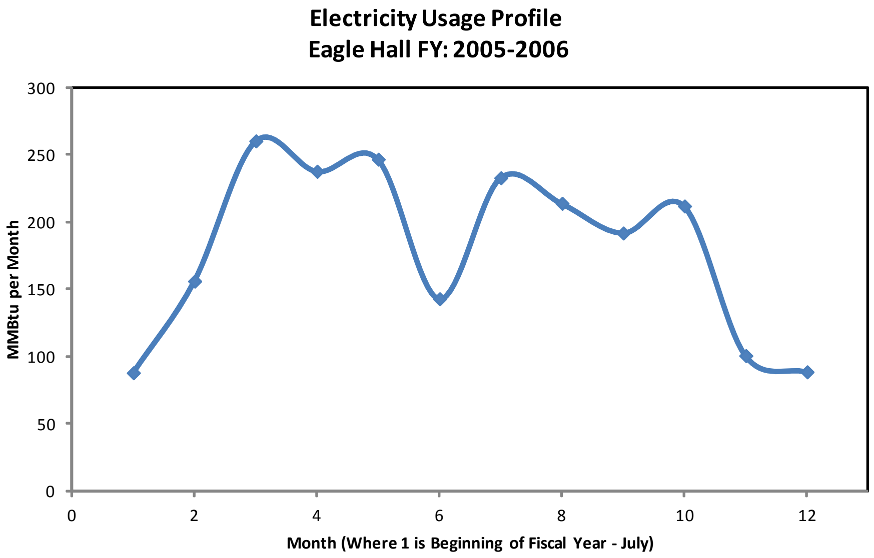
Flagrant Light Usage

Total kWh SY	509709	Lighting	160957
Sum	448334	Common Appliances	106104
		Student Plug Loads	181272
		Process Power	61375

Table A-A 8: Electricity Consumption for Eagle Hall: FY 2005-2006 through 2009-2010 (MMBtu)

	MMBTU of Electricity				
Month	**(05-06)**	**(06-07)**	**(07-08)**	**(08-09)**	**(09-10)**
July	88.03	79.85	82.51	81.18	64.83
August	156.20	148.73	170.98	159.86	159.35
September	260.46	217.86	233.00	240.92	226.91
October	237.83	261.23	235.57	257.28	228.27
November	246.84	185.79	210.51	154.91	160.37
December	143.03	136.87	136.49	142.01	137.13
January	233.05	218.30	212.58	188.32	170.61
February	213.98	183.89	179.34	191.42	184.26
March	191.97	194.87	191.69	159.69	171.29
April	212.04	197.90	206.40	216.67	198.93
May	100.78	79.64	80.53	90.08	100.32
June	88.72	63.19	61.32	48.79	63.12
Annual	2172.92	1968.12	2000.91	1931.13	1865.38

Month	**kWh**	**BTU**	**Million BTU**
July	25798	88026430	88.03
August	45777	156197607	156.20
September	76333	260459007	260.46
October	69700	237826272	237.83
November	72341	246837738	246.84
December	41918	143030153	143.03
January	68301	233052685	233.05
February	62712	213982226	213.98
March	56260	191967088	191.97
April	62144	212044129	212.04
May	29537	100784427	100.78
June	26000	88715682	88.72
Annual	636821	2172923445	2172.92



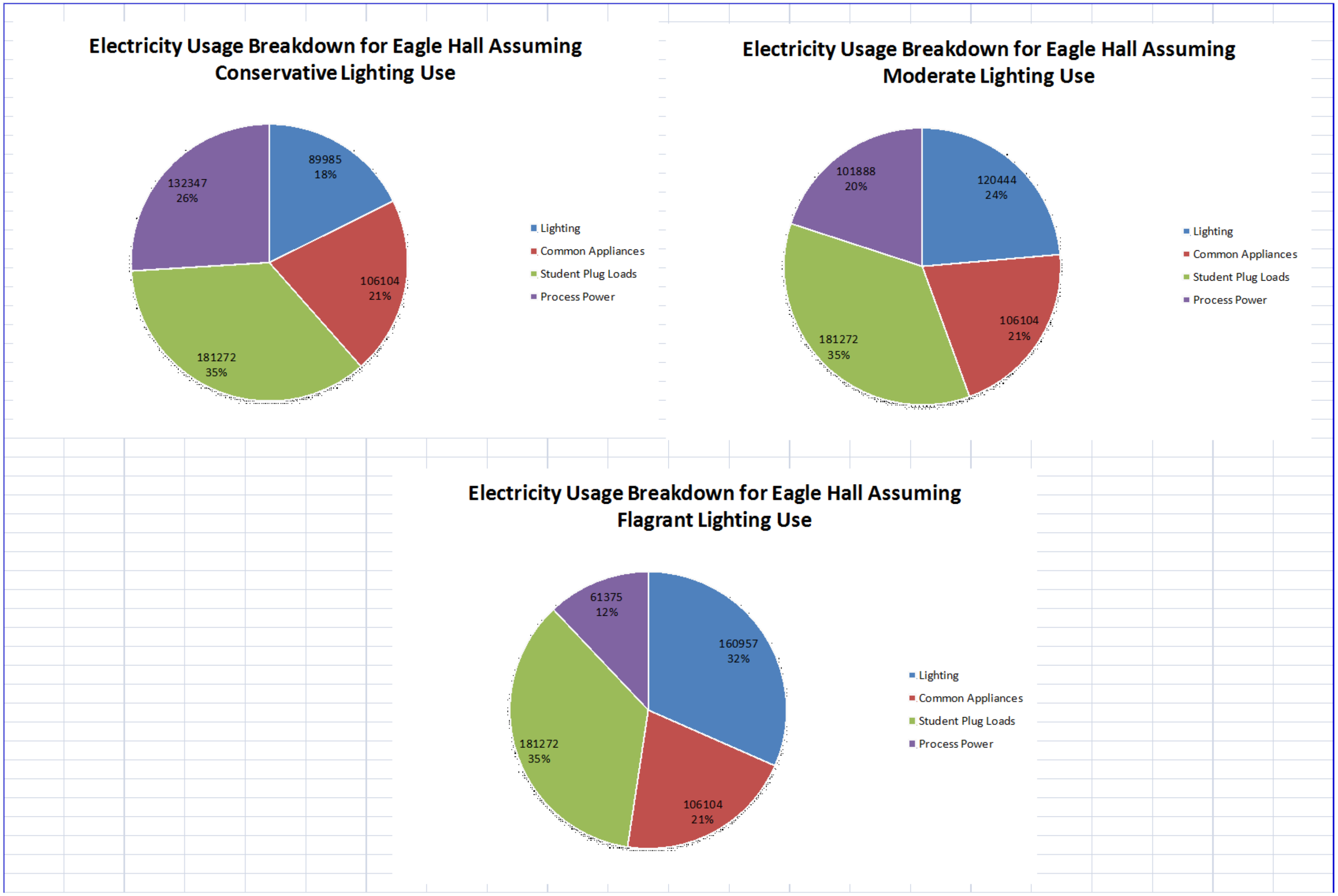


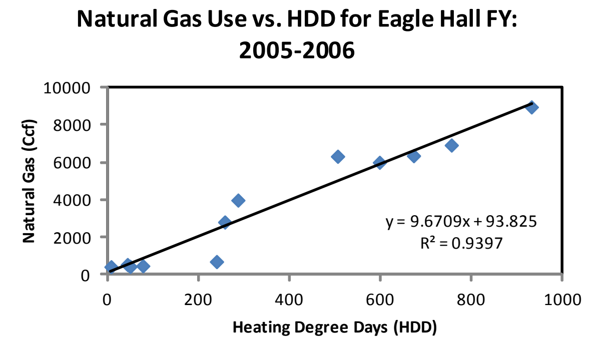
Figure A-A 1: Electricity Usage Breakdown Charts for Conservative, Moderate, and Flagrant Lighting Usages

Table A-A 9: Natural Gas Consumption and Weather-Normalization for Eagle Hall: FY 2005-2006

Eagle Hall Benchmark year 2005-2006 Natural Gas Weather Adjusted School Months with Heat On Only October - April

Eagle Hall NO AC, Heat ONLY WITH TWO BASELOADS (REGRESSION AND SEPTEMBER)

	(05-06)		HDD Averages		
Month	**Ccf**	**HDD**	**Avg (5-yr)**	**Avg (30-yr)**	**Million BTU**
July	434	8	31.6	5	44.268
August	552	44	34.2	10	56.304
September	485	78	101.6	79	49.47
October	3985	287	350.6	364	406.47
November	6320	506	586.2	651	644.64
December	8949	932	870.6	935	912.798
January	6352	673	928.6	1070	647.904
February	6917	756	876.2	884	705.534
March	5997	598	614.6	714	611.694
April	2816	258	357	428	287.232
May	711	240	191	171	72.522
June	450	50	38	22	45.9
Annual	43968	4430	4980.2	5333	



Baseload Reg	93.825
Baseload Sept	485

Month	**Ccf Nat Gas**	**NWD (Ccf) Regression**	**Adjust Ccf Regression**	**HDD (05-06)**	**Ccf/HDD**	**Avg HDD (30-yr)**	**Norm Ccf - NWD**	**Norm CCf + NWD**
October	3985	93.8	3891	287	13.56	364	4935	5029
November	6320	93.8	6226	506	12.30	651	8010	8104
December	8949	93.8	8855	932	9.50	935	8884	8978
January	6352	93.8	6258	673	9.30	1070	9950	10044
February	6917	93.8	6823	756	9.03	884	7978	8072
March	5997	93.8	5903	598	9.87	714	7048	7142
April	2816	93.8	2722	258	10.55	428	4516	4610
							Total	51978.35573

Month	**Ccf Nat Gas**	**NWD Ccf (September)**	**Adjust (Ccf) From Sept**	**HDD (05-06)**	**Ccf/HDD**	**Avg HDD (30-yr)**	**Norm Ccf - NWD**	**Norm CCf + NWD**
October	3985	485	3500	287	12.20	364	4439	4924
November	6320	485	5835	506	11.53	651	7507	7992
December	8949	485	8464	932	9.08	935	8491	8976
January	6352	485	5867	673	8.72	1070	9328	9813
February	6917	485	6432	756	8.51	884	7521	8006
March	5997	485	5512	598	9.22	714	6581	7066
April	2816	485	2331	258	9.03	428	3867	4352
							Total	51129.43726

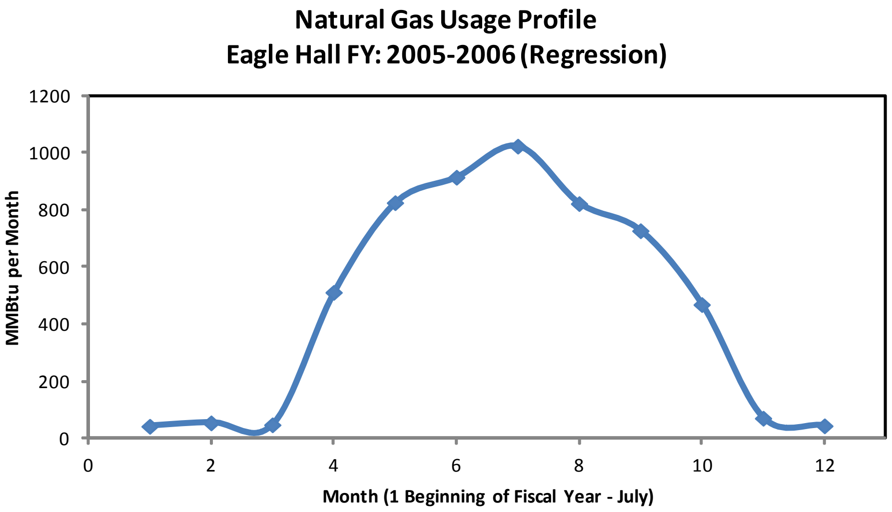
Table A-A 10: Weather Normalized Natural Gas Consumption for Eagle Hall: FY 2005-2006

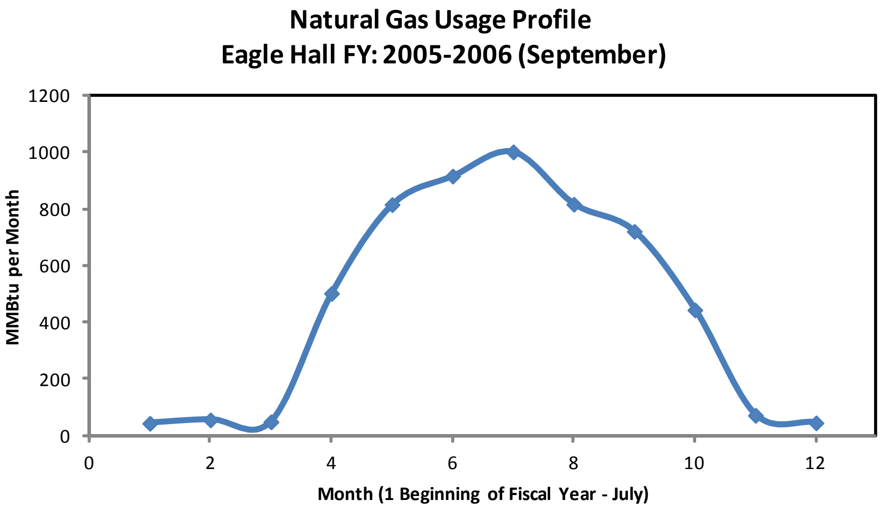
(05-06)

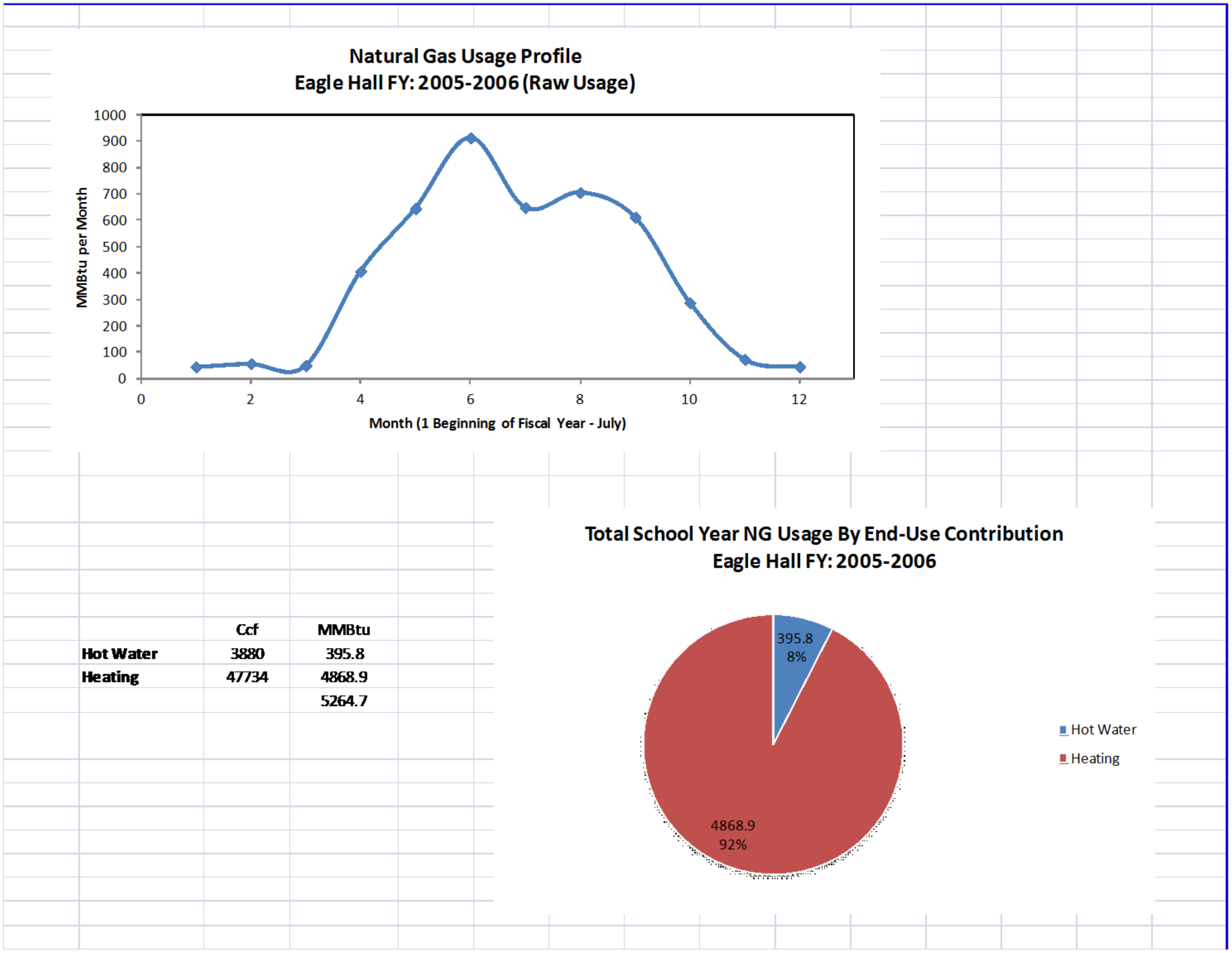
Month	Ccf	BTU	MMBtu
July	434	44268000	44.3
August	552	56304000	56.3
September	485	49470000	49.5
October	5029	512955326	513.0
November	8104	826626419	826.6
December	8978	915705386	915.7
January	10044	1024454577	1024.5
February	8072	823369149	823.4
March	7142	728493944	728.5
April	4610	470187483	470.2
May	711	72522000	72.5
June	450	45900000	45.9
Annual	54610	5570256284	5570

(05-06)

Month	Ccf (Sept)	BTU	MMBtu
July	434	44268000	44.3
August	552	56304000	56.3
September	485	49470000	49.5
October	4924	502250488	502.3
November	7992	815192668	815.2
December	8976	915576953	915.6
January	9813	1000917816	1000.9
February	8006	816613619	816.6
March	7066	720754174	720.8
April	4352	443896884	443.9
May	711	72522000	72.5
June	450	45900000	45.9
Annual	53761	5483666601	5484
			5264.7


Natural Gas Usage Profile
Eagle Hall FY: 2005-2006 (Regression)


Natural Gas Usage Profile
Eagle Hall FY: 2005-2006 (September)



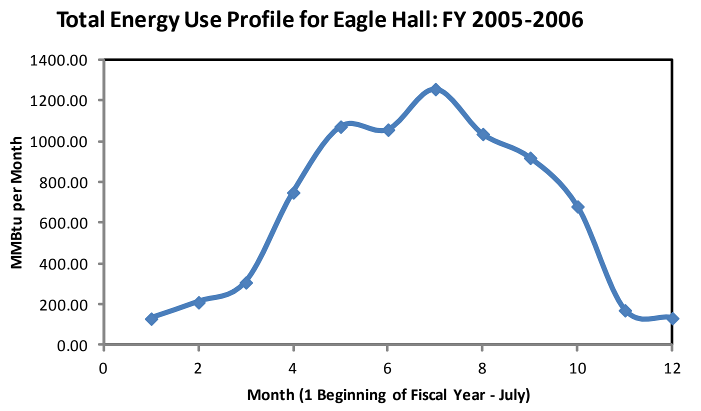
	Ccf	MMBtu
Hot Water	3880	395.8
Heating	47734	4868.9
		5264.7

Figure A-A 2: Raw Natural Gas Usage Profile and Total School Years NG Usage by End use for Eagle Hall: FY 2005-2006

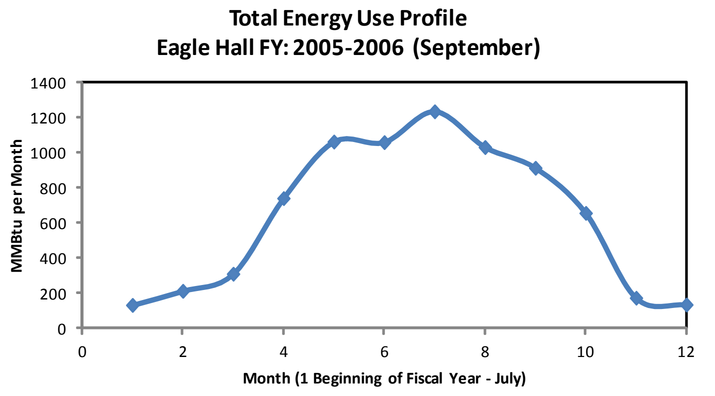
Table A-A 11: Total Energy Consumption Eagle Hall: FY 2005-2006

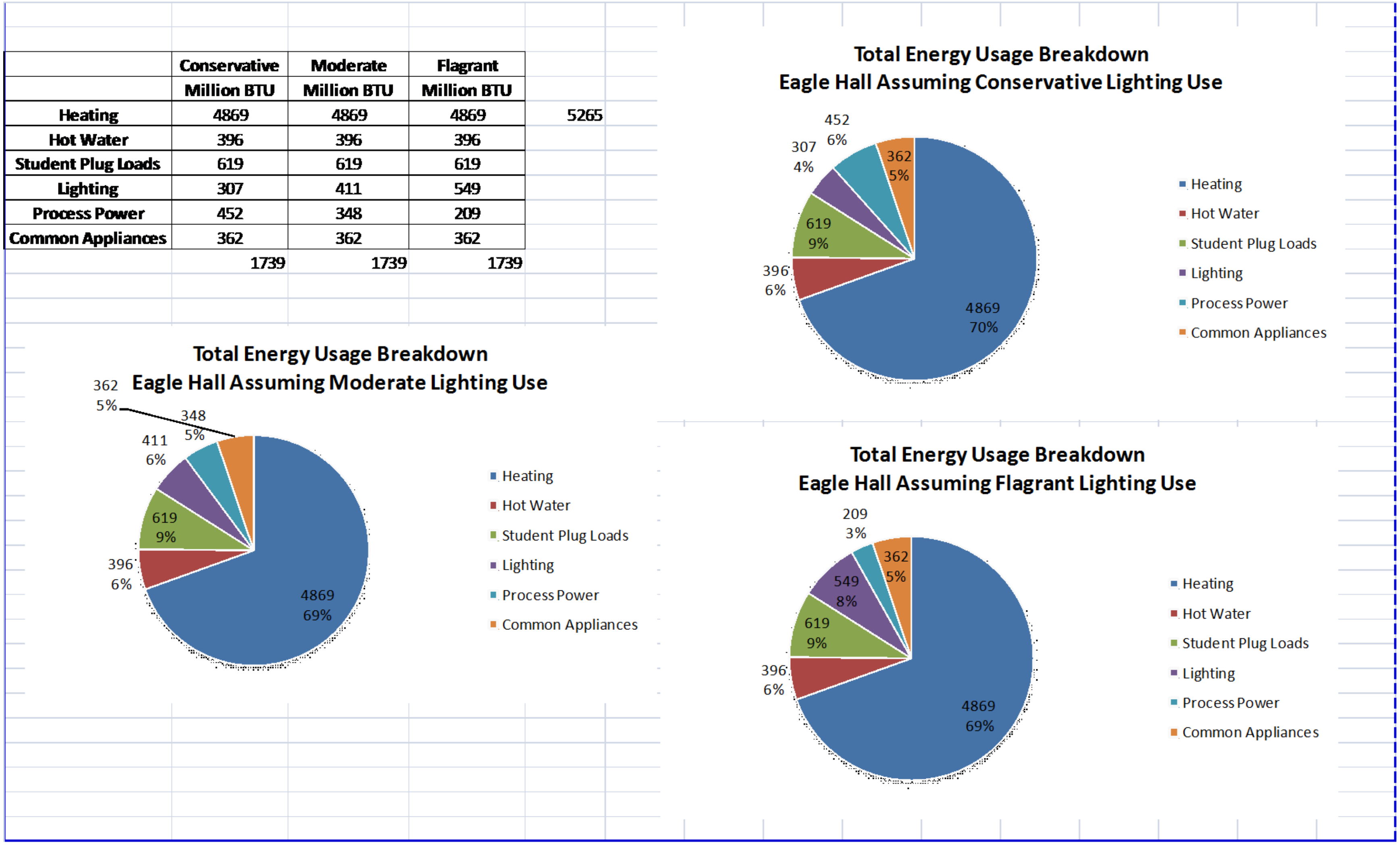
Eagle Hall Total Energy Fiscal Year 2005-2006

	Million BTU		
Month	**Electricity**	**Natural Gas**	**Total**
July	88.02642977	44.27	132.29
August	156.1976074	56.30	212.50
September	260.459007	49.47	309.93
October	237.8262716	512.96	750.78
November	246.8377377	826.63	1073.46
December	143.0301528	915.71	1058.74
January	233.0526855	1024.45	1257.51
February	213.9822259	823.37	1037.35
March	191.9670881	728.49	920.46
April	212.0441295	470.19	682.23
May	100.7844273	72.52	173.31
June	88.71568238	45.90	134.62
Annual	2172.9	5570.3	7743.18
SY	1739.2	5351.3	



	Million BTU		
Month	**Electricity**	**Nat Gas (Sept)**	**Total**
July	88.02642977	44.27	132.29
August	156.1976074	56.30	212.50
September	260.459007	49.47	309.93
October	237.8262716	502.25	740.08
November	246.8377377	815.19	1062.03
December	143.0301528	915.58	1058.61
January	233.0526855	1000.92	1233.97
February	213.9822259	816.61	1030.60
March	191.9670881	720.75	912.72
April	212.0441295	443.90	655.94
May	100.7844273	72.52	173.31
June	88.71568238	45.90	134.62
Annual	2172.923445	5483.67	7656.59
SY	1739.2	5264.7	7003.9
Btu	1739199298	5264672601	7003871899





	Conservative Million BTU	Moderate Million BTU	Flagrant Million BTU	
Heating	4869	4869	4869	5265
Hot Water	396	396	396	
Student Plug Loads	619	619	619	
Lighting	307	411	549	
Process Power	452	348	209	
Common Appliances	362	362	362	
	1739	1739	1739	

Figure A-A 3: Total Energy Breakdown Charts for Eagle Hall: FY 2005-2006

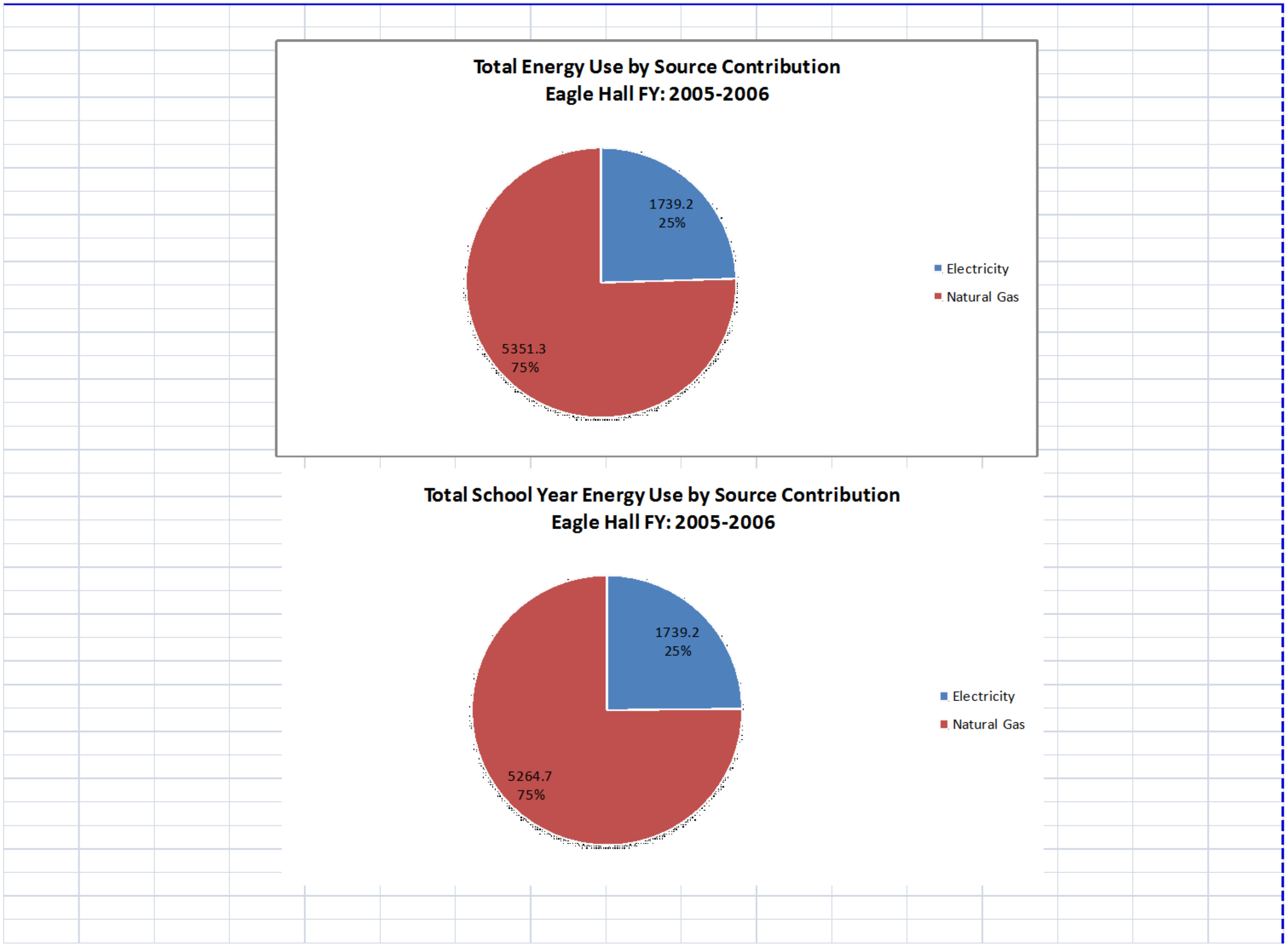


Figure A-A 4: Total School Year Energy Use by Source Contribution Eagle Hall: FY 2005-2006

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