Energy Monitoring Systems for The Printer's Building

An Interactive Qualifying Project proposal submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science.

December 17, 2009

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Abstract

The purpose of this project was to evaluate and recommend energy management systems for the Printer's Building in Worcester, Massachusetts and to develop a resource for other buildings to use. Meetings and visits were coordinated with contractors and facilities that have experience with energy management systems. It was concluded that a real time monitoring system was the best fit for the Printer's Building. As a case study, the electrical usage of Miles Press, the fifth floor tenant, was measured to determine meter accuracy and the applicability of an energy management system. This resulted in a recommendation that the floor be reviewed be by a power specialist and that at minimum, an expandable energy monitoring system be installed.

Acknowledgements

Wyatt Wade

Project Sponsor, CEO Davis Publications

Jim McKeag

Project Liaison, Printer’s Building Manager

Rob Doray

Miles Press

Steve Testa

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Authorship

This project was created from mutual contributions from all of the group members. Each member attended all group meetings and wrote an equal share of the writing that exists within this document.

I. Cahill was primarily responsible for creating the mappings of the circuit breakers in Microsoft Excel. He was also responsible for the composition of the sections of the paper that involved the on-site visits. K. Fournier was primarily responsible for coordinating the visits and meetings. He wrote the sections of the paper that involved the audit, and he was also responsible for compiling the final structure of the document. M. Kielbasa was primarily responsible for editing the CAD drawings. He also composed the sections of the paper that involved the meetings.

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Executive Summary

This project was created to assist the Printer's Building in reducing the energy consumption of the building and its tenants. Because of the building's old age, there are large amounts of outdated and inefficient devices that may need to be replaced or updated. Our Interactive Qualifying Projected (IQP) was to study different energy managing systems, determine the needs of the building and its tenants, and to determine which system was most appropriate to address those needs. Then, with the information we collected, we were to create a pamphlet that would provide a resource of the processes and our recommendations to provide a resource that other buildings suffering from the same problems can go to. While researching the possible systems, we also focused on mapping out all circuit breakers in the building, as there was no such resource previously created. We also wanted to find out if the metering in the building was being done correctly and accurately.

Methodology Overview

To complete our project goals we devised a set of methods that would guide us to making useful conclusions and recommendations for building owner, Wyatt Wade. Since we were looking at conducting an energy audit, our first step was to study the previous IQPs, one of which had already done an audit of the building. This gave us an idea of what we needed to do and what had already been done so that we could coordinate our steps effectively.

We decided that we needed to complete our own audit because more information was needed than the past group had collected. We started with the walkthrough part of an audit where we added the locations of all the circuit breakers in the building to Computer Aided Design (CAD) drawings, created by a previous IQP. To complete the next step of our audit we acquired a Fluke 1735 Data Logger from Mercier Electric. By attaching this piece of equipment to the kilowatt hour meters on the fifth floor and comparing the information we received from the data logger with what the meters themselves recorded, we determined if the meters have been taking accurate readings. With this knowledge we made recommendations as to whether the meters needed to be replaced or if they were accurate and could continue being used.

To learn about the social impacts and to get a first hand perspective of different energy management systems, we arranged visits to two local buildings: Blackstone Valley Regional High School (BVHRS) and East Hall at WPI. These buildings were chosen because BVRHS had been renovated to incorporate the new technology, and East Hall had been built with their energy management system. This gave us a comparison of a retrofit/renovation to a completely new structure. Our final step was to meet with an energy managing system specialist, a representative from Yankee Technology, Steve Testa. From the two meetings with Steve we were able to obtain an estimated cost of the system, and information for the installation and implementation.

Key Findings

The findings of this project are a result of in-depth research, and from the advice and statements of professionals and various specialists.

We determined the location of all the circuit breakers in the building, and updated the CAD drawings with the location of each individual circuit breaker. Using an Excel spreadsheet we also mapped and labeled each switch with the amount of amperage each one drew. From this information we decided to focus on the fifth floor, which is entirely operated by Miles Press. This is the most complicated floor because it has the greatest variety of equipment being used and because there had been reports of inconsistent billing. So after we had already found all the circuit breaker locations and amp ratings, we started mapping out what switch controlled what.

Rob Doray, a member of the Miles Press staff, knew what some of the switches controlled. To identify the unknown switches we began by turning all their lights and then flipping switches to determine which breakers controlled which set of lights. Once we determined this we used a circuit breaker finder to locate the switches that controlled various electrical outlets. By finding all this information out we concluded which switches controlled what devices, and saw which breakers were no longer in use.

We determined that there were two main power feeds that lead into the fifth floor. We attached the data logger to each feed separately and recorded each one's power usage for several days. These results were recorded and compared to what the meter itself read and the results we found proved that both meters on the fifth floor were accurate. However, we determined that the older dial operated meters are difficult to read and are often misread if the person reading them isn't careful. With this piece of equipment we also noted that Miles Press has a lot of reflective energy which could be damaging their transformers making the electricity company charge a premium for the damage that is being done to their equipment.

Our group also researched several different systems and met with specialists who have experience with each system. We first researched dashboard systems, which could only monitor energy usage. We then met with Steve Testa, of Yankee Technology, and he recommended WebCTRL, a software package that we also saw on our visit to East Hall. When given a demonstration of the system and its capabilities we noticed that the system not only monitored energy usage, which the dashboard systems did, but it could also control energy usage. Furthermore, WebCTRL could be accessed with any device that had an internet connection.

Finally, we created a brochure which will act as a social footprint for buildings that are similar to the Printer's Building. It will include the methods we used along with the conclusions and recommendations that we provided.

Recommendations

Over the course of this term we were able to gather and analyze data and make several recommendations for our sponsor.

1. Invest in the WebCtrl system through Yankee Technology.
2. Purchase new meters for each floor to go with the new Energy Management System.
3. Use the old telephone junction boxes for the communication trunk and wiring.
4. Have occupancy sensors installed.
5. Have a power specialist come in to evaluate the power usage for Miles Press.

Although the initial pricing for these recommendations is quite high, the system will be able to help save money in the long run by reducing the building's energy usage.

Chapter 1: Introduction

Energy consumption is a growing problem in the United States. As technological advances occur, the more we rely on technology in our everyday life. This is causing the energy being consumed to increase because there are more electronic devices that need to be powered. The four major sectors of energy consumption are industrial, transportation, residential, and commercial buildings. Commercial buildings, such as the Printer's Building, consume almost 20 percent of the energy being used in the United States. In an average office, lighting uses 29% of the energy consumed, heating 25% and office equipment, such as computers, 16% (Commercial Buildings) . This trend in energy consumption has been steadily increasing over the years and this growing problem is helping the need for energy efficiency and energy conservation grow.

Like many other older office buildings, the Printer's Building in Worcester is exploring ways to reduce its energy consumption. When we started, the meters that monitor the energy on the fifth floor appeared to be inaccurate. The first thing we needed to do was determine how accurate the meters were, and what caused the inaccuracy. The project team determined the needs of the Printer's Building by conducting an audit of the fifth floor, occupied by Miles Press, and its metering devices. With this information the building manager could determine how necessary an energy management system was, and it allowed Miles Press to become aware of their usage so that they could become more conservative of the energy they are using. Davis also wanted this project to become a resource for similar buildings that would like to become more energy efficient. We created a pamphlet that included how our project was completed, what tools were necessary, what we found, and our recommendations. Once a new energy management system is installed, it will be able to monitor the energy usage per tenant, allow for remote control of equipment, and it will also be able to adapt to a new HVAC system that is planned to be installed in the future and further increase the energy efficiency of the Printer's Building.

Chapter 2: Literature Review

2.1 Energy Use in the United States

Energy is used in almost every aspect of life, but energy use is a growing problem in the United States that is often over looked. Figure 1 shows the four major categories (industrial, transportation, residential, and commercial) that consume the most energy in the United States. Commercial buildings use energy the least according to this study. However, for the amount of commercial buildings compared to the amount of residential structures, or the size of industrial buildings compared to commercial buildings, they have a large consumption. A lot of the manufacturing and industrial side of business is being exported to other countries. As more and more commercial buildings are built there is going to be an increase in the percentage they consume. This can also be attributed to the increase of the involvement of technology in everyday activities that are typically done in a business.

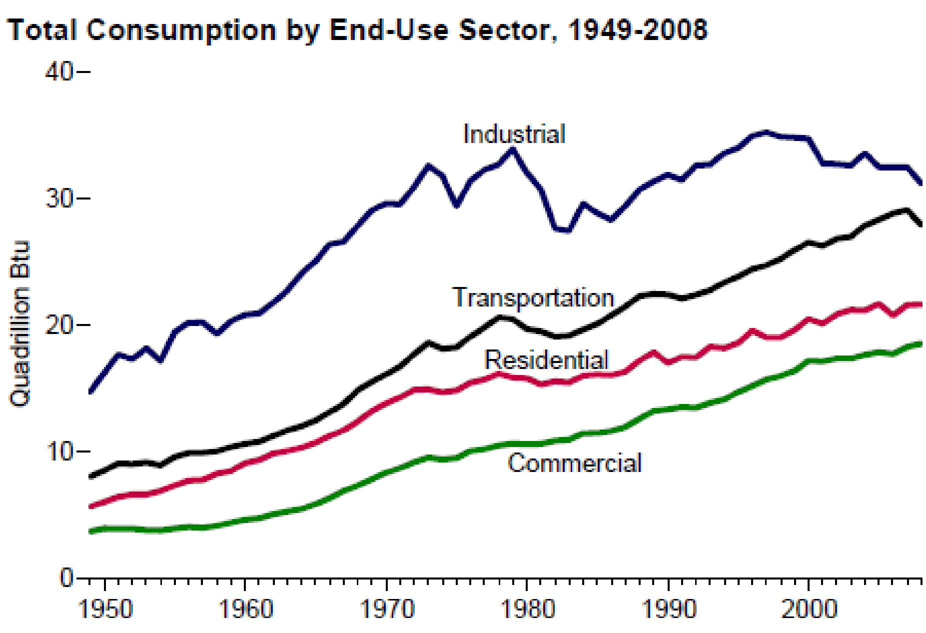

Figure 1: Total Consumption by End-Use Sector, 1948-2008 (Energy Consumption by Sector Overview)

2.1.1 Office Energy Use

Office buildings consume energy in many different ways. From Figure 2 we can see that the main use of energy in office buildings is lighting. Fortunately, lighting can be controlled in different ways using different energy monitoring systems through things like motion sensors. Lots of times, areas of buildings are lighted when there is little or no activity. Motion sensors could be added to buildings in those areas so that the lights turn on only when someone passes by the sensors. The second greatest use of energy in buildings is office equipment and some examples of such are; computers, printers, and copiers. Many buildings waste large amounts of electricity by leaving these pieces of equipment on when they are not in use. Simply shutting the equipment off could easily save on the energy consumption when they were not being used. If the devices cannot be shut off, putting them into a standby mode or a sleep mode would also help to reduce the energy use in the building.

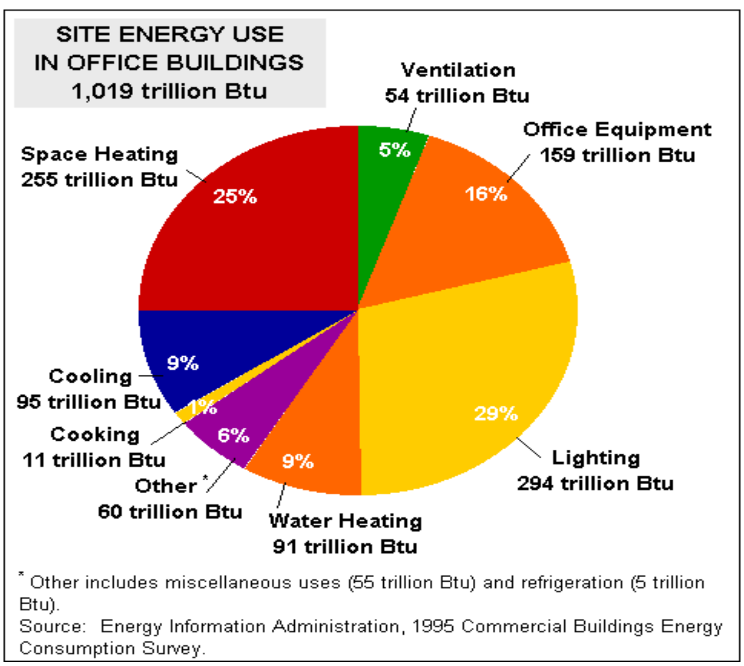

Figure 2: Site Energy Use in Office Buildings (Commercial Buildings)

As seen in Figure 3, older buildings, such as the Printers Building, use more energy per square meter than newer buildings. They consume more energy because of their older pieces of equipment not being able to use energy as efficiently as some of the newer buildings with new equipment. Because of this, older buildings such as the Printer's Building need to discover ways to conserve energy.

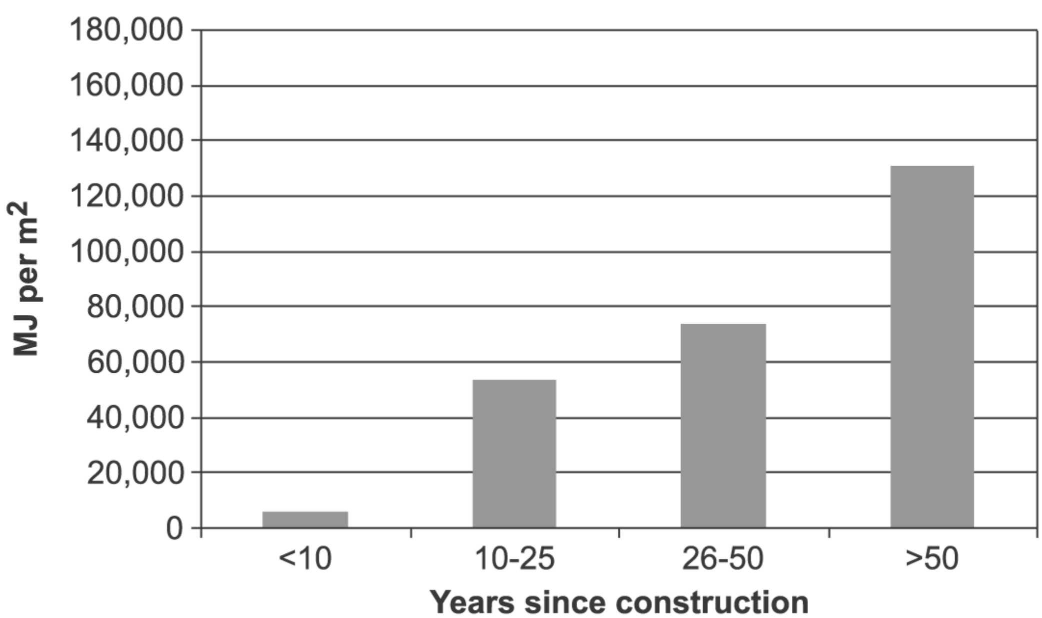

Figure 3: Energy Use By Building Age in Office Buildings (Wilkinson & Reed, 2006)

2.2 The Printer's Building

The Printer's Building is a seven story, concrete structure that stands at 44 Portland Street in downtown Worcester, Massachusetts. The building was constructed in the late 1920s by three printing companies that wanted a building to accommodate both printing and binding machinery. The building was built at a time when energy conservation was not a primary concern, and the materials, as well as the heating and cooling systems, are relatively inefficient compared with modern facilities. The Printer's Building is interesting particularly because of the way it was constructed. It was built specifically with the thought of being able to hold very heavy loads on each floor, and that was the main focus of the building. The weakest floors of the building are on the top two floors, and they can withstand 150 pounds per square foot load. In order to have the building be this strong, it was constructed out of concrete. The problem with having a building made of concrete is that it is difficult and expensive to insulate effectively. The floors are No. 1 -7/8 inch maple flooring two and a quarter inch wide placed on two inch thick spruce planks bedded in tar and sand layer (Wesby, 1922).

The windows of the building are old and not as insulated as newer windows. The windows on the Portland Street side are wooden double hung sash and are equipped with Chamberlain Weather Strips. The other windows on the other three sides are rolled steel sash with polished wire glass on lower two panes and the upper three rows wire glass polished one side. These windows do not provide adequate insulation (Wesby, 1922). There is also a stack on the building is of buff radial brick construction, 120 feet high. The internal top diameter is three feet one inch; cross section of base is five feet eight inches, and round in shape (Wesby, 1922).

The power current of the building is 220 Volts A.C. 3 phase 60 cycles, and the lighting current is 100 Volts. There are meters installed on every floor that monitor the energy used by the tenants of that floor. However, a problem with these meters is that they could be inaccurate and tenants are not getting billed correctly. Another problem with the electrical system is that energy is being wasted when certain parts of the building are not in use (Wesby, 1922).

Fortunately, the Davis Corporation is committed to reducing its energy use and would like to serve as a model of energy use and conservation for other older buildings in the area to follow.

Figure 4: The Printer's Building (Davis Publications, 2009)

2.2.1 The Printer's Building Today

Today the Printer's Building retains much of its original structure, but only one floor uses printing equipment now, which is done by Miles Press on the 5th floor. Most of the building is rented out to various other tenants (Table 1). The tenants include Davis Publications (3rd floor), WICN (a local jazz radio station on the 1st floor), a film company operated by Andrea Ajemian (4th floor), Whipple Construction (2nd floor), and WPI's Worcester Community Project Center (7th floor). Davis Corporation owns the building with Wyatt Wade serving as the President and Chief Executive Officer. Today, about thirty five percent of the building is used for office space, ten percent for manufacturing, and fifty five percent for storage.

Tenant	Sq. Ft.	# Employees
Davis Publications	41317	30
Miles Press	11894	11
WICN	4710	5
Maintenance	2689	4
R.L. Whipple Co.	2200	10
WCPC	1933	N/A
Andrea Ajemian	1643	3
Edward Street	994	3

Table 1: Tenants at the Printer's Building (McKeag, Tenant Summary, 2009)

2.3 Energy Audit

There is a general plan for conducting an energy audit, but there are many types of audits that are derived from that plan. According to Mr. McKeag, the audit that was done previously was a very basic audit that consisted of data analysis and a walkthrough (J. McKeag, Personal Communication, September 14, 2009). The different types of audits range in complexity based on the number of steps that are involved. More complex audits are able to generate more in-depth results, but they can be costly and time consuming. A level 1 energy audit focuses on low- and no-cost energy efficiency measures and operational improvements and provides great ROI for its moderate cost. This is usually the best place to start an energy management effort. A level 2 energy audit focuses on specific energy efficiency measures that require some capital investments but yield an attractive ROI. A level 3 energy audit is an investment-grade engineering study conducted after capital investment dollars are budgeted and the organization can justify a comprehensive study of all major energy savings opportunities in a building. (Lubinski, 2008)

2.3.1 Historical Data Analysis

The first step in an audit is to do a *historical data analysis*. This is when information is gathered from previous electricity and utility billings and also possibly through correspondence with the electrical company which is a common alternative. Using this data, the bills can be analyzed and an energy pattern for the building can be developed (PQA INC.). Typically, such analyses examine three years of utility data, identify the fuel types used in the building, and determine the patterns of fuel use by identifying the peak demand for energy, the effect of weather on fuel consumption, and energy use by building type and size (Krati 2000). Such simple audits identify the most costly months for energy use and indicate where a building may be wasting energy and money.

2.3.2 Walkthrough

Companies may choose to do a historical analysis instead of a *walkthrough* because a walkthrough requires a professional auditor to come on sight and do an evaluation. In a walkthrough audit the auditors walk through the building and take note of inadequate equipment and also use certain tools such as a thermal imager to find heat loss (Gager, Gould, Lampke, & Jeffrey, 2008). The walkthrough audit requires a complete equipment inventory, including all major energy-consuming equipment and lighting, and photographs of the building should be taken as well (Energy Management Systems). The occupancy and use of the energy in each area of the building are also important according to Moncef Krarti, a professor at the University of Colorado (Krarti, Moncef Krarti Ph.D.,PE, 2001). Walkthrough audits examine areas such as the HVAC system type, the lighting type and density, the equipment type and density, and what type of energies are used for; heating, cooling, lighting, equipment, etc. (Krarti, Energy Audit of Building Systems: An engineering approach, 2000). After all the data from the walkthrough is collected, a cost analysis is completed and recommendations are made.

2.3.3 Baseline

The third step is to *create a baseline* for the building energy use. This is when architectural, mechanical, electrical, and control drawings are obtained and reviewed. Then, the building equipment is tested to see how each piece performs and to test their reliability. Also during this step, the auditor wants to obtain all the schedules for operation of any equipment from the tenants in the building as to be able to calculate an accurate baseline model for the energy use in the building at any given time (Krarti, Energy Audit of Building Systems: An engineering approach, 2000).

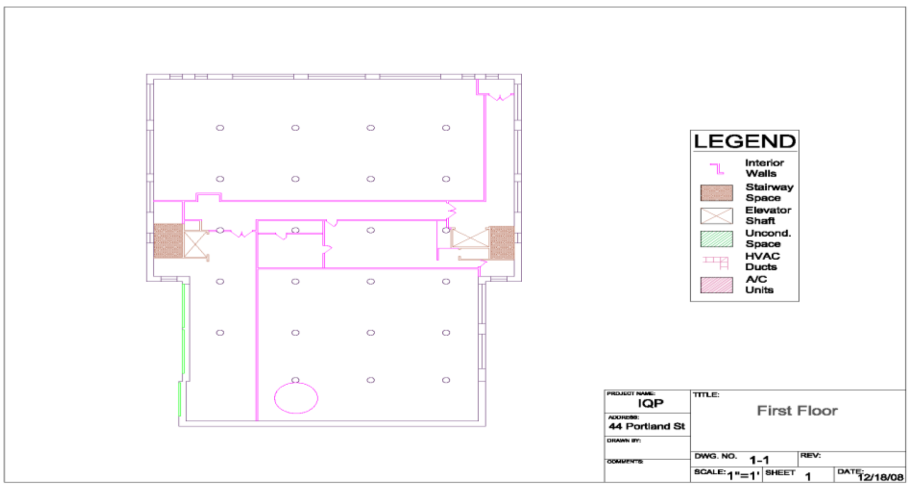

Figure 5: CAD Drawing of the First Floor

The last step of the process involves the *evaluation of possible energy saving measures*. This is when the auditing group would put together a list of possible conservation methods found in the initial walk through. These may be things such as simply changing old lights to new fluorescent ones, or to start using energy efficient lamps or ballasts. Also, things that may need to be changed could be fax machines, printers and copiers, even computers themselves. There are new types of office equipment that have an Energy Star rating issued by the EPA that would help to reduce the amount of energy being used. Another typical thing that may be suggested is that additional thermal insulation may be needed.

The next part of step four involves using the data from the baseline in step three; with the data found one should be able to determine the energy savings due to the various methods that could be incorporated through their study. Lastly, the group needs to evaluate the initial cost of the new equipment and see how long it takes for the return (Krarti, Energy Audit of Building Systems: An engineering approach, 2000). With the best choice decided for them by the calculations they can now make recommendations to the company as to what they can do to reduce energy consumption. This step is often merged with step two, because if you do not have a baseline completed, the baseline cannot be analyzed to determine the energy savings from the possible recommendations.

2.4 Energy Management Systems

An energy management system can only be operable if there is multi-point monitoring and multi-point control. This means that rather than having one point on a floor with a thermostat that controls the whole floor, there would be a breakdown into individual areas with more control points. Another thing an EMS can do is shut devices down when not in use they can make that determination by way of a timer or the installation of sensors. This will help and save energy for different power applications.

The first need of an energy management system is to have a way of monitoring the usage of power throughout the building. The current meters that track usage do not fully assist Davis Corporation in calculating the usage, because it is not known how each meter is hooked up, and exactly where they are hooked up to. The energy management system will account for when power is actually needed and record it. This could range from HVAC to the electricity draw on the circuits for each floor. What is good about an energy management system is that it is not asked to over perform. Instead it focuses on monitoring, and will only be managed when it is told to do so

Previous IQP's with Davis Corporation have focused on the lighting and HVAC systems at the Printer's Building, so our group will continue the overall audit by adding new information. How the systems are controlled is a major factor in the selection of an energy management system as well. Jim McKeag, the building manager, is very concerned as to how he will manage the energy, and needs to know the positives and negatives of each control option (J. McKeag, Personal Communication, September 14, 2009). Older buildings such as the Printer's Building will encounter several problems when trying to install an energy management system.

One problem is that they often have to be installed using old, pre-existing equipment. Although this could save money, it could cause problems with installation if the old equipment is not big enough for the EMS. Another problem is that older buildings are almost constantly undergoing renovations and change. This makes having an EMS to be very difficult as it has to be allowed to undergo changes itself and be adaptable to the new changes. Another problem is it has to be accommodating for the present tenants.

The system has to be installed while not interfering with the tenants who work there, and then once installed the system cannot disrupt them in their work. It has to be coordinated with incentive and retrofit programs, so that an upgrade in one part of the building will still be compatible with the EMS. Finally, the last problem of older buildings is that the EMS has to be affordable. When knowing the initial costs of the system, the buyer must take into account that upgrades may have to be done, not only to the building but also to the system.

2.4.1 Requirements for Energy Management System

Because of the unique setup of the Printer's Building, the monitoring of energy usage in all the different parts of the building is very important. The composition of multiple tenants throughout the building makes it important that Davis Corporation knows who is using how much energy at all times. Some of the businesses, such as Miles Press and WICN, have equipment that pulls large amounts of energy, whereas the Worcester City Project Center uses comparatively little (J. McKeag, Personal Communication, September 14, 2009). To offset this difference, the different tenants pay utility bills based on what the meters display for their usage. Due to the age of the meters, and because the building manager is unsure of what every meter is monitoring, the current system may be inaccurate (J. McKeag, Personal Communication, September 14, 2009). Adapting our research to the unique aspects of the Printer's Building will be an important part of our project.

The way in which the building manager controls the energy management system has a major influence on the decision of which system is the correct fit for the Printer's Building. There are very simple systems that automatically make changes based on a timer. More complicated systems use the internet and computers to receive commands from a centralized control center. (Sharma, 2003) With the use of sensors, the most convenient way to install them is to have one main center that houses the controls the system. However, as HVAC systems have evolved it is now relatively easy to install a sensor in each room using wireless technology. (Lin, Clifford, & Auslander, 2002) The ability to place sensors in each of the different areas of the Printer's Building, will help accommodate the energy control needs for the majority of the tenants.

A major part of integrating an efficient power system at the Printer's Building is the ability of the system to mesh with other energy efficiency systems in the building. With the recommendations from prior WPI IQP groups, management at the Printer's Building has discovered ways to improve the efficiencies of the lighting and HVAC systems. If the energy management system doesn't work with those other systems, then its benefits are not maximized. Researchers at the University of California-Berkeley found that management systems that utilize sensors can be easily integrated into any building control system. (Sharma, 2003) Using an easily integrated monitoring system with a sensor-based management system the Printer's Building could become more efficient. The decision as to which system would be the best fit for the Printer's Building will be assisted by the completion of an energy audit.

2.4.2 Lucid Design Dashboard

Several systems are available that might assist the Printer's Building in energy monitoring. Lucid Design Group in Oakland, California has launched such a system called Building Dashboard which displays the energy usage on a computer screen. Energy consumption data is collected in the building and then is sent to the company's servers. The servers then analyze the information they have received and display charts of the building's energy consumption. The competition setting, Figure 6, will compare the different parts of the building to each other, which could allow for the Printer's Building in calculating what share of the energy consumption is consumed by which tenant. This program is adaptable to most energy management systems, so any new systems that are installed in the Printer's Building can be integrated with the Lucid Dashboard. This system can cost anywhere in the range of $10,000-$50,000 for installation (Center for a Built Environment, 2009). The Lucid Dashboard could be a beneficial system to be implemented by the Printer's Building.

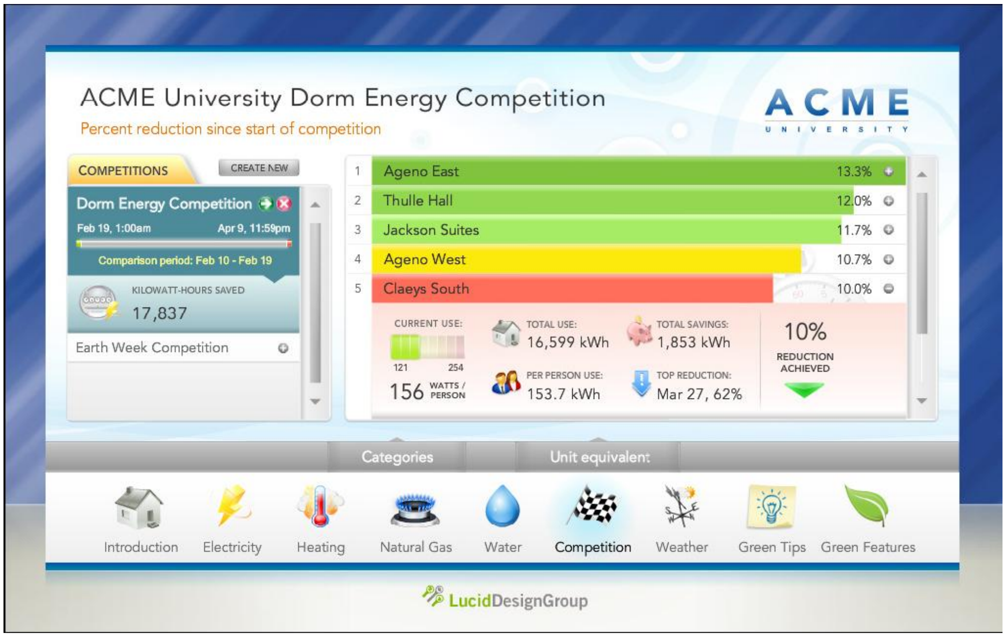

Figure 6: Display of a Competition (Center for a Built Environment, 2009)

The University of Colorado at Boulder recently installed the Lucid Dashboard in two of its buildings, Libby Hall and Davis Hall. The University claims that the programs biggest asset is how user friendly the Dashboard is and the ability for anyone with internet access to view the program. Also, the ease of access to the amount of energy usage has contributed to the decrease of energy usage in the buildings. They also state that the program can be adapted to fit the energy monitoring needs of a building (Lewis, 2008).Screen shots of the Dashboard installed at University of Colorado at Boulder can be seen in Figures 7 and 8.

Figure 7: Electricity Usage at UC Boulder (Lewis, 2008)

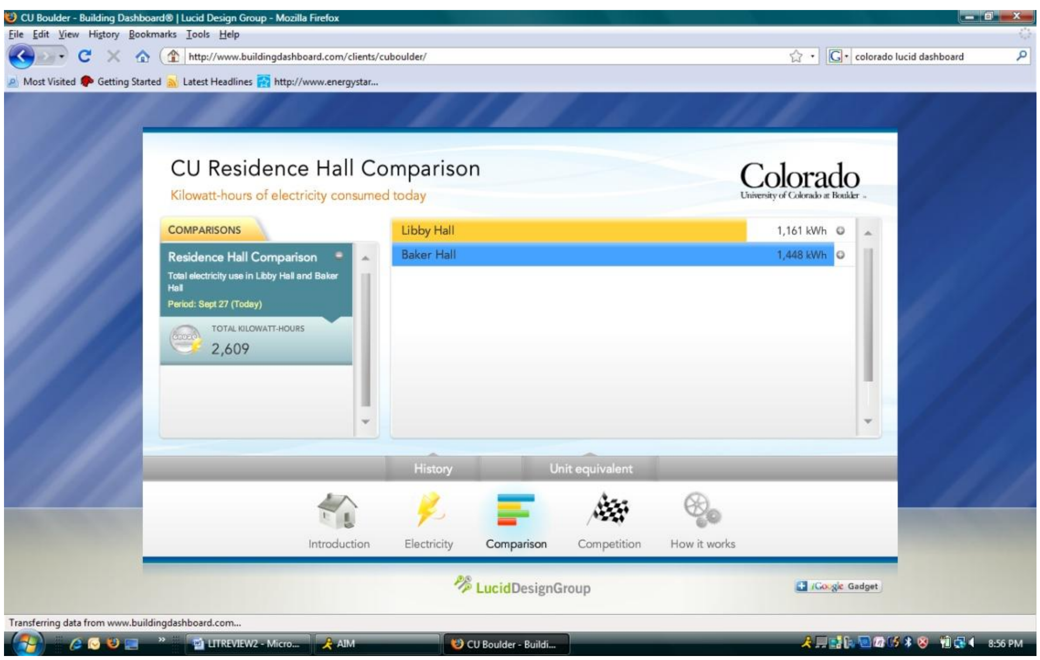

Figure 8: Electricity Usage Comparison (Lewis, 2008)

2.4.3 Agilewaves Dashboard

Another energy monitoring system that could be advantageous to the Printer's Building is called the Agilewaves Dashboard (Figure 9). Similar to the Lucid program, Agilewaves' results can be accessed from any computer that has an internet connection and it operates from a server that is installed in the building. This dashboard has the ability to inform the user what the energy usage in the building is by area, room, or appliance, and it can be measure over different time intervals. Initial purchase of installation of this system typically costs about $15,000 (Center for a Built Environment, 2009). The Agilewaves Dashboard would be utilized more completely by the Printer's Building because its main feature is the ability to detect different energy usages, and can even monitor different appliances.

Figure 9: Agilewaves Dashboard (Center for a Built Environment, 2009)

Users of the Agilewaves Dashboard have discovered the ways in which they were consuming excess energy and have been able to adapt their energy usage to be more efficient. Bob Miller, Owner of the Miller Design Company who utilizes the Agilewaves system, proclaimed, “I had no idea our computers and night lighting were costing us so much! We had no idea that the exterior landscape lights were staying on 24 hours a day! The Resource Monitor really made our entire office aware of what we use.” (Miller, 2008)

2.5 Summary

The literature review summarizes our research for the implementation of an energy management system into the Printer’s Building. This information guided us in creating a plan for how our project was to be conducted. The following chapter, the methodology, provides our planned steps that were based on our research.

Chapter 3: Methodology

3.1 Overview

The methodology provides the planned steps that we took in order to complete our Interactive Qualifying Project. The goal of this project was to present to our sponsor, Wyatt Wade of Davis Publications, an energy management system that could be used in the Printer's Building. Along with improving the Printer's Building, our sponsor wanted this project to become a social footprint for similar buildings to use in order to better manage their energy usage.

In order to understand the energy usage of the Printer's Building, we completed several steps of an energy audit. Our group focused specifically on Miles Press because it had the greatest variety in its power usage. Located on the fifth floor, Miles Press uses all of the typical equipment of an office; computers, lighting, fax machines, printers, copiers, etc, but they also have massive printing equipment that uses a large amount of energy. Our group also visited buildings in the area that have energy management systems installed that appeared to be what the Printer's Building might be interested in.

3.2 Yankee Technology

In order to learn about different Energy Management Systems, we contacted Yankee Technology, a contractor who markets energy management systems. Our main goal was to learn about different systems that were available, and the steps needed to be taken in order to install them. We also wanted to find different metering devices that could measure energy usage, and also function in an energy management system.

After learning about different systems and the options that are available, we researched as to what would be the best fit for the Printer's Building. After further research into their products, as well a tour of a building that had their EMS installed in it, we decided to have a second meeting with Yankee Technology. Our goal for this second meeting was to obtain an estimated cost to install the system and present them with the information we found that would be needed for installation of the system. We also discussed the possibility and feasibility of future upgrades to the system. Whether the HVAC would be able to be incorporated into the system later on was a main concern for Jim McKeag, and we wanted to make sure that the system would be adaptable

3.3 East Hall

In order to see the system that was recommended to us by Yankee Technology, our group visited East Hall, the newest dormitory on campus at WPI. Assistant VP of operations, Alfredo Dimauro, Mechanical Operations Super, Norman Hutchins, WPI Chief Engineer, Bill Grudzinski, and Brent Arthaud from Cardinal Construction presented the East Hall EMS. The building was built in the beginning of March 2007 with the goal of becoming LEED Silver certified, but it was actually able to attain a gold rating (A. Dimauro, Personal Communication, November, 23, 2009). The computer based interface that they use to monitor and control energy usage, WebCtrl, was our main focus during the visit.

When we first contacted Fred Dimauro, WPI Facilities Manager, we asked if we could arrange a tour of the building and to view their energy management system in action. We were hoping to get a good idea of the abilities of the WebCtrl software and get an idea about the usability of its interface. Two features that we wanted to learn more about were scheduling and the troubleshooting system for WebCtrl. Scheduling allows the user to automate temperature controls by programming temperatures for certain days and times. Learning about the features of the system was important, but we also wanted to know how the system actually performed.

Figure 10: East Hall at WPI (Epstein, 2008)

In viewing the EMS we wanted to hear any comments about the system as to how well it worked and if the system has worked as promised. We wanted to ask the facilities personnel if there had been any problems in controlling their system. Also, we wanted to know if any of the students in the building had had complaints. After viewing and hearing about their system we decided to setup another meeting with Yankee Technology to get into more detail about the possible installation of WebCtrl.

3.4 Blackstone Valley Regional Vocational Technical High School

One of the buildings that our group visited was Blackstone Valley Regional Vocational Technical High School (BVRHS). In 2005 they renovated the high school, and it now serves as an example for other buildings trying to become energy efficient. We were referred to BVRHS by our contact at National Grid. The majority of the building was completed from new construction instead of retrofit, but in terms of the energy management system it was still a good opportunity to see a system in it application.

Figure 11: Blackstone Valley Regional High School (Blackstone Valley Regional Vocational Technical High School, 2009)

There were a couple of main objectives that our group had for our visit to BVRHS. We wanted to find out what energy management system they were using for monitoring their energy usage. Also, our group wanted to know if they monitored areas of the building separately, or, if they did not monitor separately, if they had the option to. The Printer's Building is planning on making HVAC renovations in the near future, so our group was also interested in what types of HVAC system BVRHS used and how well they worked with their energy management system.

Through the visit to BVRHS, our group was able to discover one possible energy management system that could be installed at the Printer's Building. We conducted further research on the energy management system, which was manufactured by Andover Controls, to find out its abilities and if it would work at the Printer's Building. With the information that we discovered about the system, we compared the system to others that we discovered to make a decision as to whether or not to recommend the system.   .

3.5 Walkthrough

In order to figure out what equipment the Printer's Building would need to integrate an energy management system, we needed to map out where the major electrical equipment throughout the Printer's Building was located. This was completed by doing a walkthrough of all the floors, searching for the locations of all of the circuit breakers and master switches, recording their location on the floor plans to the building, and then diagramming each individual circuit breaker. The location of each circuit breaker was drawn on the CAD drawings of the building, and the circuit breaker diagrams were put into an excel file. With this information we determined where the monitoring needs to take place and we can give this information to Yankee Technology if they are contracted out to install the WebCtrl system.

3.6 Establishing a Baseline

To establish the accuracy of the meters on the fifth floor and to create a reference for the power usage for our project we created a baseline for the energy usage by Miles Press. We did this by using a FLUKE 1735 Three Phase Data Logger that we borrowed from Mercier Electric. This piece of equipment has four flexible current probes, one for each phase and then the neutral cable, three voltage leads, and can log up to forty five days of data.

Figure 12: Fluke 1735 Data Logger (Fluke, 2009)

There are two main power feeds into the fifth floor. There is one that leads into the women's restroom closet, 5D in Figure 13, and one that leads into one of the men's restrooms, kWh meter 15A in Figure 13. In the closet of the women's restroom there is the number 15 kilowatt hour meter, a main circuit breaker, and various smaller ones. The main circuit breaker is a direct feed for the floor, and it is also connected to the kilowatt hour meter, so this is where we attached the Fluke data logger.

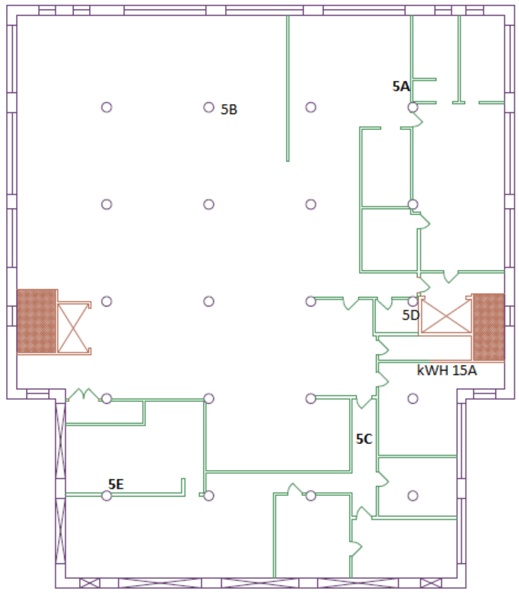

Figure 13: CAD Drawing with Circuit Breakers

Unfortunately the cables that run into the main breaker pass through a poorly organized box that contains transformers. This made it particularly difficult to identify which cables were the match for their respective voltage leads. We solved this problem by using the power option on the data logger which measures the kilowatts (kW) going into the breaker through the probes, and measured the kilovolt amps (kVA) when the leads were attached. The kW was then divided by the kVA to give a ratio of how much power was actually being used. When the probes were not matched with their respective leads the ratio had a negative value. With the equipment set up properly we recorded the current data that the kWh meter read and we left the Fluke data logger in the closet to log the power being used through the number 15 kWh meter and then moved it to the 15A kWh meter afterward.

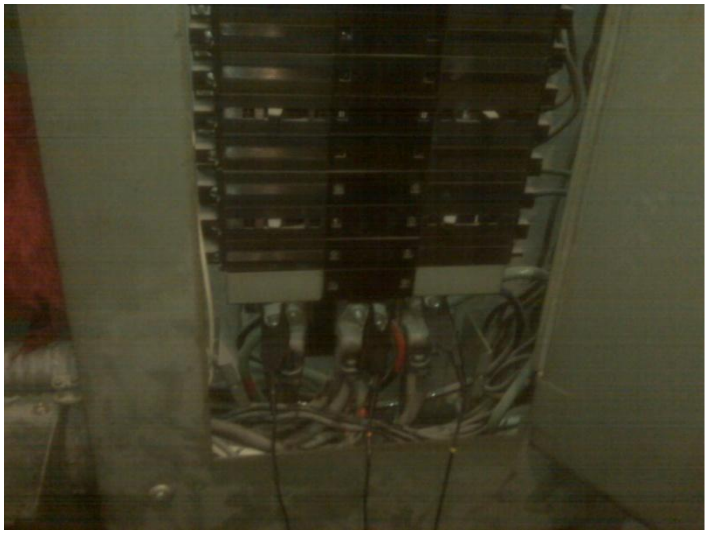

Figure 14: Leads attached to the three power cables connecting to the breaker (Kielbasa, 2009)

3.7 Project Schedule

A schedule is presented below that displays when all of the methods were completed throughout the term. These methods included meetings, conducting a walkthrough, creating a baseline, formulating recommendations, analyzing data, and creating a pamphlet of our methods and results.

Tasks	Week 1					Week 2					Week 3					Week 4					Week 5					Week 6					Week 7				
Schedule Meetings and Visits																																			
Walkthrough																																			
Meetings and Visits																																			
Baseline																																			
Formulating Recommendations																																			
Analyze data and put together contacts																																			
Pamphlet																																			
	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F	M	T	W	R	F
	26	27	28	29	30	2	3	4	5	6	9	10	11	12	13	16	17	18	19	20	23	24	25	26	27	30	1	2	3	4	7	8	9	10	11
	October					November																					December								

Table 2: Project Schedule

Chapter 4: Results

This chapter of our report highlights the results from all of the tasks that were outlined in the methodology. These results were used to guide us in making our final conclusions and recommendations for the Printer's Building.

4.1 East Hall at WPI

The most intriguing feature we found in the system that East Hall uses was the ability to manage energy usage in real time. However, we also found that the feature that allows for scheduling can make managing the building a lot easier. During the visit it was mentioned that the facilities department uses scheduling to automate the energy management system (N. Hutchins, Personal Communication, November, 23, 2009). This ability could allow the building manager to set up an automated schedule for energy usage, and adjust it in real time when necessary.

For the Printer's Building, it is important to be able to monitor different parts of the building separately because there are different tenants for each floor and they have to be billed accordingly. Mr. Dimauro mentioned that the WebCtrl system allows the user to control the system in each room separately, as seen in a screen shot in Figure 15, but they do not monitor the total usage individually by room. However, Mr. Dimauro mentioned that the monitoring can be as granular as necessary, it just increases the cost.

Installation of sensors allows the automation of a system to become more accurate and fine. East Hall has occupancy sensors within each common room so that if the room remains empty for 12 hours the HVAC system reduces the expected temperature and the lights are powered off (A. Dimauro, Personal Communication, November, 23, 2009). The occupancy sensors could be useful tool for the Printer's Building in controlling lighting and heating in areas that aren't occupied on a constant basis. Similarly, there are zone temperature sensors in each room so that, when the temperature falls below a set point the high efficiency condensing boilers will turn on. However, this is possible for East Hall specifically because each dorm has a separate boiler. If the Printer's Building were to have similar sensors it may require many boilers throughout the building which would prove to be very expensive.

Figure 15: Screen Shot of WebCtrl (Automated Logic, 2007)

East Hall uses a chilled water and hot water HVAC system. They use two chillers for the building that are set to automatically turn off when the outside temperature reaches 60 degrees Fahrenheit (N. Hutchins, Personal Communication, November, 23, 2009). The chillers are water cooled products that are manufactured by Smardt. The chillers work with an oil-less compressor that works at variable speeds and operates on relatively low current, approximately 2 amps (N. Hutchins, Personal Communication, November, 23, 2009). East Hall is able to condition

103,610 square feet of living using only those two chillers (Worcester Polytechnic Institute, 2007).

4.2 Yankee Technology

In our meeting with Yankee Technology they showed us the actual system that was installed at Williams College. All that was needed to gain access to the control system was a computer with internet access combined with a username and password. This type of software would prove beneficial and useful for the building manager, who would be able to access the information for the building from any computer with internet access. The software described showed the temperature of each room and controlled the temperature of the room. The unit also displayed the amount of energy consumption over an adjustable period of time. All of the systems installed by Yankee Technology are customizable to meet the needs of the company as the one at Williams College probably has different needs than the Printer's Building(S. Testa, Personal Communication, November 5, 2009).

Yankee Technologies uses Veris Industries for their energy sensors which are used largely in Building Automation Control applications. One of the main reasons we were interested in Veris' products was because they are working toward systems that are adaptable to other companies' products by creating an industry standard. This would mean that the Printer's Building would not be forced to only purchase Veris equipment for future renovations once they purchased Veris meters because the meters would be adaptable to products made by other companies.

One meter that Veris makes is the H81xx Series Energy Meter. This meter can be used for sub metering, performance contracting, allocating costs, and real-time power monitoring via local display or through control/data acquisition systems. The real time power monitoring would allow this meter to connect with an energy monitoring system to give instantaneous and historical readings of energy usage. This system could be very useful to the Printer's Building since they have multiple tenants and want to see the amount of energy each one uses (Veris Industries, 2008).

Figure 16: H81xx Series Energy Meter (Veris Industries, 2009)

Another meter we researched was the H84xxV/VB/VBS Series digital power meter. Some applications of this meter are energy managing and performance contracting, sub metering for commercial tenants, activity-based costing in commercial and industrial facilities, and real-time power monitoring via local display or through control/data acquisition systems. It is similar to the H81xx, but its analysis of cost can divide the cost by process within the building. This is also another device that could be of use to the Printer's Building (Veris Industries, 2008).

Figure 17:H84xxV/VB/VBS Series digital power meter (Veris Industries, 2009)

Veris Industries also supplies a various amount of products for HVAC and temperature control which could be of use to the Printer's Building in the future. Along with these HVAC products from Veris, Yankee Technologies recommended a company called Building Automated Products Inc (BAPI), which also has a various amount of HVAC products that the Printer's Building could use in the future. These range from chilled water devices to energy efficient heating systems. For instance, they created systems that can tell when a window is open, so that when the window is opened the heating or air conditioning system will shut off. This could be particularly useful to the Printer's Building, because there are so many different areas of the building that have varying amounts of heating and air conditioning.

4.3 Visit to Blackstone Valley Regional Vocational Technical High School

Our tour of BVRHS gave us a chance to observe some of the new technology that is used today. One of the most impressive features of the building is its usage and control of lighting. The lighting is controlled in four different ways; by motion sensors, daylight sensors, switches, and through main controls of the energy management system (S. Grabowski, Personal Communication, November 5, 2009). Sunlight tubes were also used throughout the building. These tubes were placed on the roof to collect sunlight and then the sunlight was funneled through a tube of mirrors into a room where it would appear as a normal light. BVRHS also used high efficiency boilers that could burn either gas or oil, so they could utilize the cheapest fuel, and these boilers run in series so that they would never have to run at maximum capacity (S. Grabowski, Personal Communication, November 5, 2009). These controls combined with the functionality of the system allow the building to be less wasteful of energy.

BVRHS also uses solar energy for supplying part of their electricity demand. On the roof there are over 200 solar panels that collect energy for the building. Although the panels are a great way to generate energy, a simple cost analysis shows that they are not a good financial asset. Steve Grabowski estimated the cost of the panels to be $500,000, but he thought that the panels saved the high school around $10,000-$15,000 per year (S. Grabowski, Personal Communication, November 5, 2009). With those estimates, the payback period on the solar panels is over 30 years.

Figure 18:BVRHS Solar Panels (Blackstone Valley Regional Vocational Technical High School, 2009)

BVRHS installed an energy management system that is produced by Andover Controls. The lighting sensors that were installed in BVRHS are part of the EMS, and there are many other options that they provide. Their Crysalis Sensors are able to monitor humidity and temperature in a room. Also, override control is available for these sensors, but they are generally used in conjunction with Ezset software to control the temperature from a computer (Schneider Electric). The energy monitoring system made by Andover is called TAC Vista. Vista allows the user to monitor and change energy usage from any computer with an internet connection, and it monitors the different power loads separately (Schneider Electric, 2008). It can monitor each room individually if necessary, so it would be able to monitor the separate tenants properly. Andover's EMS seems as though it could fit the needs of the Printer's Building, but it does not seem to be adaptable to other companies' products. This could be a problem for future renovations at the Printer's Building because it could limit the options for new systems since they would have to purchase Andover products.

4.4 Second Meeting with Yankee Technology

From our first meeting with Yankee Technology we learned that we had several tasks to complete before our next meeting with them. Our first task was to fully map out the circuit breakers on Miles Press, this way we knew what breaker powered which piece of equipment. Rob Doray, a member of the Miles Press staff, knew what some of the switches controlled. To identify the unknown switches we began by turning all their lights and then flipping switches to determine which breakers controlled which set of lights. Once we determined this we used a circuit breaker finder to locate the switches that controlled various electrical outlets. By finding all this information out we were able to conclude which switches controlled what devices, and saw which breakers were no longer in use.

This data was used in the next meeting with Yankee Technology as it assisted them in designing their Energy Monitoring System. During the meeting, a Yankee Technology representative, Steve Testa, presented us with a Utility Monitoring Proposal. This document included the scope and pricing of what needed to be done to install an Energy Monitoring System. The installation of the EMS for the Printer's Building would be broken into four separate phases of installation.

The first phase would be the EMS platform. The EMS will be web based and using the industry standard open protocol which is BACnet (A Data Communication Protocol for Building Automation and Control Networks). The software being used will be WebCTRL, in figure 1 it can be seen that WebCTRL can be accessed through any internet browser, such as Internet Explorer. The system will have the capability to create trends on every system point and be displayed in color graphics which also can be imported into an Excel or PDF format. Figure 2 shows an example of WebCTRL, and its color coded scheme representing various temperature zones for each particular room. Yankee Technology will setup the entire program on a computer, provide detail drawings of how it is connected, and assist the owner in operating the software. The final cost for this phase is $14,950.

Figure 19: WebCTRL Log in Screen (Automated Logic, 2007)

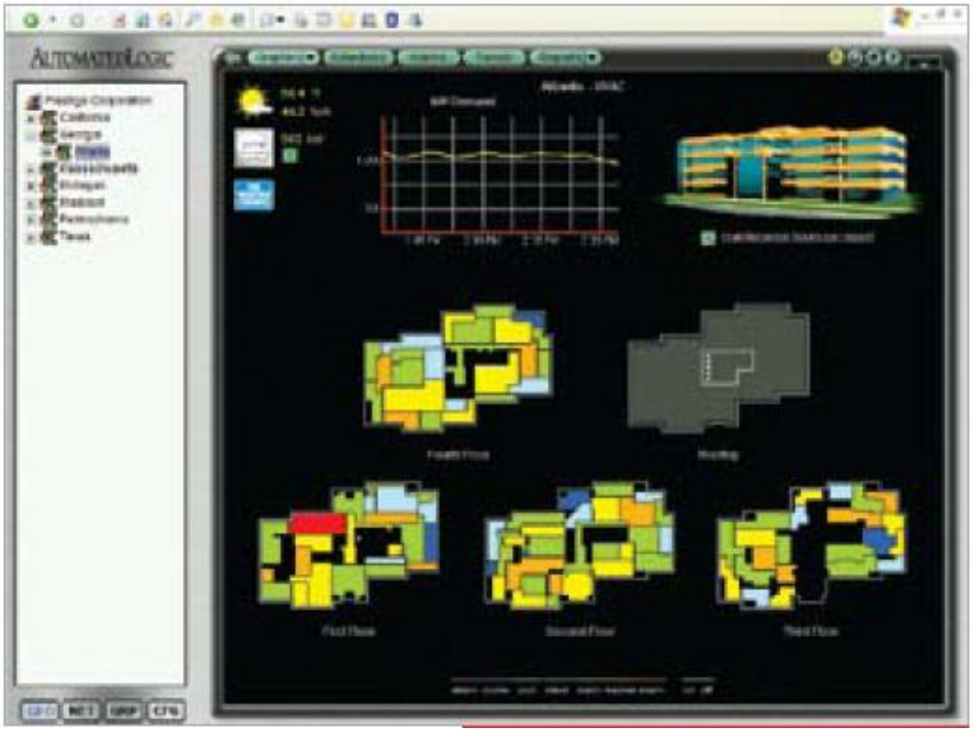

Figure 20: Screenshot of WebCTRL (Automated Logic, 2007)

The second phase would consist of the installation of the communication trunk. The recommendation for phase 2 is to install the communication trunk through each of the seven floors including the basement and have a landing at each floor for future install of Direct Digital Controls (DDC) controllers. This measure will allow for the addition of systems to be added onto the EMS with little effort and will be done by simply running the communication trunk on it. A pre-existing telephone junction box will be converted to this panel, since the box is no longer in use, and already has conduit connecting between each of the floors. In order to use this box, the phone company will have to be contacted and confirm that the box and its wires are no longer needed and so that no codes are violated. To complete this phase the cost would be $20,452

The next phase of the installation process will be to obtain and install the equipment that is needed to monitor the electrical wattage and watts per hour. Figure 3 shows the Veris H8036-2400-4 energy meter. This piece of equipment would act as the main building electricity monitor. In this phase a baseline will be established for what the existing conditions are and for energy consumption and energy demand. The cost of this phase is estimated at $3,246.

Figure 21: Veris H8036-2400-4 Energy Meter (Veris Industries, 2009)

The fourth and final stage of the complete installation is to use the Veris meters to sub meter each floor. There would be a meter installed on the main bus duct for each floor that would be connected to the communication trunk. The total cost for this phase would be $2,650 per meter, resulting in an estimated cost of $21,200 for all seven floors. Optionally each tenant would be able to buy extra meters for use in their office space. The estimated cost for each of the meters and their installation is about $1,500.

This plan will be used to provide an EMS throughout the entire Printer's Building. However the plan is to start with Miles Press and if the system is liked by Miles Press the installation will begin for the rest of the Printer's Building. The total installation cost for the entire building would be $59,848.

4.5 Data Logger

Once the Fluke 1735 Data Logger was setup and finished recording the data was analyzed with the help of Professor Bitar. The results were placed onto an Excel spreadsheet to help and organize the collected data.

4.5.1 Meter 15

This was the main meter for the floor and also the meter that was hooked up to the majority of the printing presses. The main purpose of this part of our project was to determine if the meter was monitoring the energy usage correctly. The usage was recorded over the course of four regular workdays and four non workdays.

When we first hooked up the data logger, the meter 15 read 3975 kWh and when we detached the equipment it read 3804 kWh, a difference of nine. The data logger recorded that the consumption for the time we had it attached was 695.01kWh. From this value it was determined that the meter had a multiplication factor of just below eighty. The building management already assumed that the factor was eighty, and when we used that as the multiplier the meter actually recorded that Miles Press was being charged for usage of 720 kWh. This value was determined to be within the tolerance for the meter.

The next concern given from the data logger was the amount of active and reactive energy being produced. Active energy is the amount of energy being charged to the bills, and reactive energy is energy that bounces back towards a transformer causing damage. Active energy is the energy measured in kilowatt hours, and reactive energy is measured as kilovolt amps. From the data we recorded, the amount of reactive energy is 628.71 kVARh.

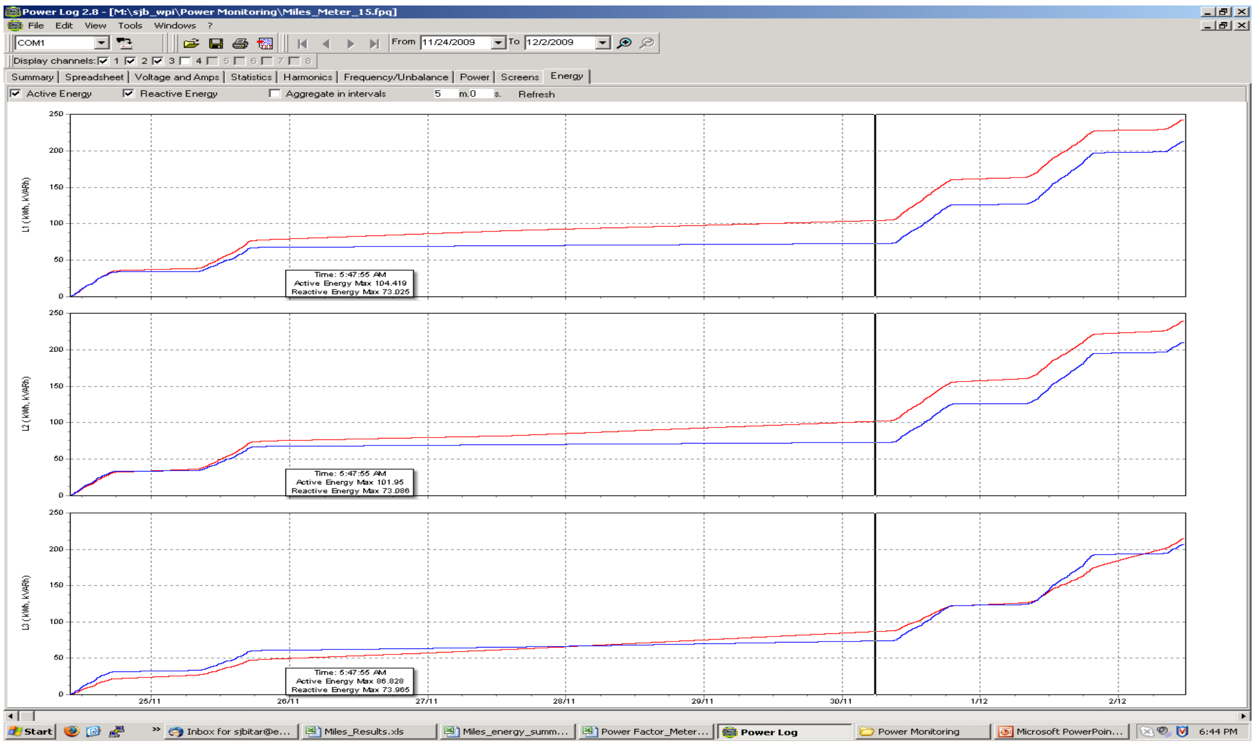

Figure 22: Total Active Energy (kWh) vs. Total Reactive Energy (kVARh)

Figure 22 shows the graph of the active energy and total reactive energy produced by the meter 15. The red line represents the total active energy and the blue line represents the total reactive energy. Preferably, the blue line should be zero, but as you can see this is not the case on this graph. Instead the reactive energy is almost equal to the amount of active energy produced, and on the third graph it is even greater in some points. This is a problem that the electricity company knows about and will charge a premium fee to cover the wear and tear on their equipment. This value prompted us to recommend that a power specialist come in and evaluate the presses and their power usage. They should determine if they could be hooked up differently or possibly add a capacitor to help save money and produce less reactive energy.

The power factor was also a problem that was noticed because of the data logger. The power factor is defined as the ratio between the real power flowing to the load to the apparent power. The recorded power factor for this meter was 0.652 on an average workday. The ideal power factor would one, meaning that there was no wasted energy. Table 3 shows a summed up results section from the data logger.

WPI PRELIMINARY REPORT				
Miles Press - Meter 15 Location				
Fluke 1735 Power Logger				
	From	To	Total Active Energy	Total Reactive Energy
	11/24	12/2	**695.01 kWh**	628.71 kVARh (BAD!)
Meter 15	Start	End	Difference	
	3795	3804	**9**	
			80	Existing Meter Multiplier
			720 kWh	**Meter is within tolerance.**
Average Daily Use =			152.2 kWh	per workday (4 day ave)
			20.8 kWh	per non-workday (4 day ave)
Power Factor =			0.652	workday average
			0.817	non-workday average

Table 3: Meter 15 Data

4.5.2 Meter 15A

The Fluke Data Logger was attached to Meter 15A from December 4 to December 7. This meter monitored the power use of a few pieces of machinery, but focused mainly on lighting and outlets in the back office. Although the data could not be recorded over the course of a full work due to time constraints, there was still very useful data pulled from the time period we did have the data logger attached.

The data logger recorded that the total energy usage was 120.5 kWh. When the logger was first hooked up meter 15A read 35411 kWh, and when it was removed the meter read 35531 kWh. The difference of these is the total amount of energy consumed over the period of time which came out to be 120 kWh. This result is extremely close to the 120.5 kWh recorded by the data logger. This information proved that the meter was accurate and billing was being correctly done.

The next step was to compare the reactive energy to the active energy produced. Figure 23 shows the graph of the three different loads.

By comparing the total active energy to the total reactive energy produced one can see that the blue line, the reactive energy, is much closer to zero than it was with meter 15. A reason why this meter is consuming less reactive energy is because it mainly controls only lighting and electrical outlets. It does not have to deal with the great amount of energy consumed from the large printing presses that meter 15 has to sustain.

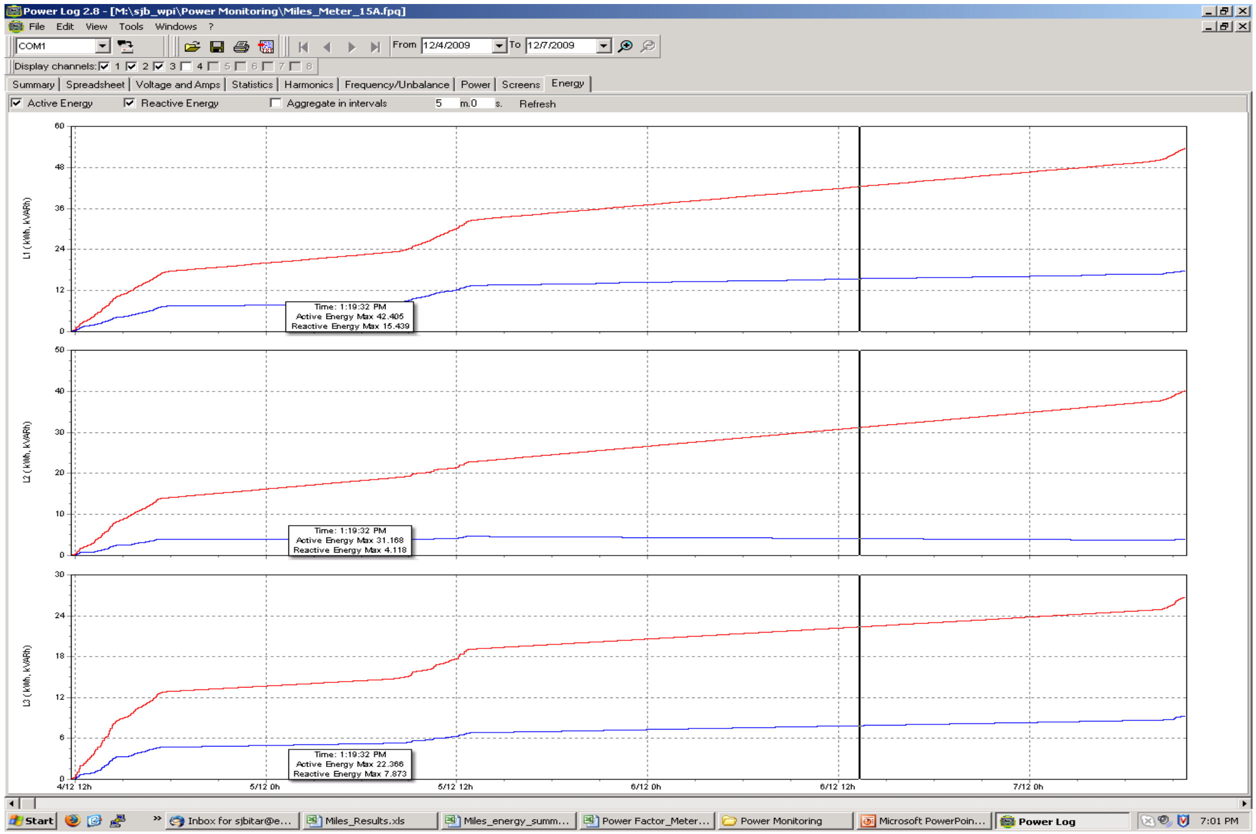

Figure 23: Active Energy vs. Reactive Energy for Meter 15A

The power factor for this meter was also much closer to the ideal value of one. The value recorded was 0.901 for an average workday. This means that there is little wasted energy. The power factor is much better than the other meter because of the loads it controls. This further led us to recommend that a power specialist be hired to take a look at the connection and power of the printing presses.

Table 4 represents the data recorded from the data logger. The amount of energy consumption per an average workday is an estimate based on six hours of a workday and two hours from another workday.

WPI PRELIMINARY REPORT				
Miles Press - Meter 15A Location				
Fluke 1735 Power Logger				
	From	To	Total Active Energy	Total Reactive Energy
	12/4	12/7	**120.5 kWh**	31.0 kVARh
Meter 15A	Start	End	Difference	
	35411	35531	120	Meter reads kWh directly.
			120 kWh	**Meter is within tolerance.**
Average Daily Use =			** 61.9 kWh	per workday (1 day ave)
			21.0 kWh	per non-workday (1 day ave)
Power Factor =			0.901	workday average
			0.807	non-workday average

** Estimate

Table 4: Meter 15A Data

Chapter 5: Conclusion

The purpose of this project was to conduct an energy audit of Miles Press and to implement an energy monitoring system into the Printer's Building. To achieve these goals we developed a series of objective. The first step was to conduct a small scale audit on the Printer's Building. This was done to give us a guide and a base to start our project. The second objective was to research an energy managing system that could be applicable to the building. This was done through research on our own and by professionals. Once we discovered the most appropriate system we provided information to our sponsor. The final objective was to monitor the energy usage of Miles Press. This was done by first, acquiring the correct equipment. Then collected the data from the device and then analyzed it and made recommendations.

The walkthrough part of the audit proved to be very useful to the Printer's Building. Using the Computer Aided Drafted (CAD) drawings from the previous IQP, we mapped out the locations of every circuit breaker on every floor. During this step we also mapped out each circuit breaker, to show the breakers on each panel and how much current each switch contained.

Another part of the audit, the baseline, proved to be a challenging task. The first step was to acquire the correct equipment in order to monitor energy usage. We did not receive the data logger until more than halfway through the term. With limited amount of time, we did not gather as much data as we had anticipated. However, we were still gathered some very useful information.

Over the course of the term we have established several recommendations for the Printer's Building, in regard to the system recommended at the end of the project. We recommend that they utilize the tools that we have created and compiled for their best interest. The product document will provide all the current information about the product and its specifications. It will show how the system is installed and accessed. The pamphlet provided will also serve as an important document. This document will show a brief description of what we accomplished and our final system recommendations. This will serve not only as a tool for the Printer's Building, but it will also serve as a guide for similar buildings.

The group's initial goal in the proposal was to conduct an energy audit of the entire building. But our group focused on the fifth floor because it the most complex in regard to its energy usage. We focused more on this floor since Miles Press has many printing machines, lighting, and typical office equipment.

The group thoroughly enjoyed working on the project over the course of the last seven weeks. We compiled a great amount of data for our sponsor and Miles Press. He can begin utilizing this data and go ahead with the upgrades to the building. The work we have completed over the last fourteen weeks will help and make the Printer's Building a more energy efficient building. Along with benefiting from these recommendations, the Printer's Building will hopefully serve as a guide to other older buildings to become more energy efficient, by installing Energy Managing Systems.

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Appendix A: Pamphlet

Problems in Printer's Building

- Multiple Tenants—installation and use of a system cannot interfere
- Has to work with the old construction of the building
- Requires retrofit and renovations because there will be more upgrades
- Needed to be coordinated with future changes

Energy Management Systems

- Allows for real time monitoring of energy usage
- Detects (or is scheduled for) when a person is in the room and makes appropriate changes in energy usage

Simple Examples:

- Programmable thermostat
- Zone controls

More Complex Systems:

- Occupancy Sensors
- Window/Door Sensors
- Individual Zone Monitoring
- Centralized Control– Allows user to control anywhere in the building from one location

First Step

- Walkthrough of the entire building
- Mapped out all the electrical components such as circuit breakers and meters
- Each circuit breaker was added to a CAD file and was mapped out on an excel spreadsheet
- This was done so that different types of energy usage(HVAC, plug load, lighting, etc.) could be separated to different circuit breakers if needed

Circuit Breaker on the Second Floor

Second Step

- Contacted a company specializing in energy monitoring systems, Yankee Technologies
- They recommended a system of theirs called WebCtrl.
- This system showed it can monitor HVAC and electrical usage.
- It could also control and troubleshoot the HVAC system

Example of a screenshot from WebCtrl

Recommendations

Install the Basic WebCTRL System

1. WebCTRL Softwar = $14,950

2. Communication between all floors = $20,452

 - used pre-existing telephone box.

3. Main Electric Metering = $3,246

4. Sub meters for each floor = $21,200 ($2,650 per floor)

Total Cost = $59,848

** If a tenant wants to monitor their individual loads, they can install an additional meter for approximately $1,500.

Worcester Polytechnic Institute

100 Institute Road
Worcester, MA 01609

E-mail: printersigp09@wpi.edu

Energy Management Systems

Worcester Polytechnic Institute

The Printer's Building
44 Portland St.
Worcester, MA

Appendix B: Sponsor Description

The Printer's Building is a seven story, concrete structure that stands on Portland Street in Worcester, Massachusetts, as seen in Figure 12 and Figure 13. The building was constructed in the late 1920's by three printing companies who wanted a building that could incorporate both printing and binding. The ability to support such large equipment made the building structurally advanced for its time (Davis Publications, 2009). The Printer's Building is a structure of about 94,000 square-feet (Gager, Gould, Lampke, & Jeffrey, 2008). Today, about 50% of the building is used for warehouse storage and 35% is office space (J. McKeag, Personal Communication, September 14, 2009). The operating budget of the building is about $440,000 per year (McKeag, Tenant Summary, 2009). [1]

Figure 24: The Printer's Building (Davis Publications, 2009)

[1] Based on an average using 2005-2009 projected data

Figure 25: Location of Printer's Building (Mapquest, Inc., 2009)

Today the Printer's Building is very different than it once was. About 67,000 square feet of the building is rented out to various tenants, including Davis Publications, WICN, a local jazz radio station, a film company operated by Andrea Ajemian, Whipple Construction, Miles Press, and the Worcester Community Project Center (McKeag, Tenant Summary, 2009). Davis Corporation owns the building with Wyatt Wade acting as the President and Chief Executive Officer (CEO) of the company. The radio station, WICN, is located on the first floor of the building. The film company is on the fifth, and the Worcester Community Project Center is located on the top floor (Davis Publications, 2009). Seventy employees work in the building, 30 of which are employed by Davis Publications as seen in Table 2. Handling the competing needs and desires of the different tenants makes building management a complicated process

Tenant	Sq. Ft.	# Employees
Davis Publications	41317	30
Miles Press	11894	11
WICN	4710	5
Maintenance	2689	4
R.L. Whipple Co.	2200	10
WCPC	1933	N/A
Andrea Ajemian	1643	3
Edward Street	994	3

Table 5: Tenant Summary (McKeag, Tenant Summary, 2009)

Davis Press was founded in the late 1800's in Worcester, Massachusetts. In 1901 the first issue of School Arts magazine was published and established a publishing branch of business for Davis Press. The magazine was published so that there would be a resource to teachers of art in schools, and School Arts, another Davis Press company, also started publishing resource books in 1902. In 1958 Davis Publications was born out of necessity because the publishing of resource books was becoming the main focus of the business (Davis Publications, Inc., 2009).

Davis Publications was established as a separate company under Davis Corporation. In 1968, the company started publishing text books, and by 1980 the company was offering textbooks at the junior high and high school levels. In 1995 Davis acquired Rosenthal Art Slides which made the company able to offer a greater range of choices in new technology and multimedia resources. In the 1990's when the presses besides Miles Press closed, Davis Corporation took ownership of the Printer's Building and continues to own it to this day. The company is in its fourth generation of family management as the CEO Wyatt Wade is married to Gilbert G. Davis' great granddaughter.

Figure 26: Wyatt Wade (Twitter, 2009)

Mr. Wade (Figure 14) was born in New Orleans and studied for his bachelor's degree at the University of Texas. He is very enthusiastic about the potential for 'green technologies' in Worcester, and he feels the ability to transport so many people throughout the city through public transportation is a good step toward green technology. His love for green technology may stem from the fact that he became disappointed by Houston because of all of the oil industries that control the area. (Fletcher, 2006) The Printer's Building is a great target for energy efficiency upgrades as shown by a study done by John Straube, a professional engineer with a PhD. in building philosophy. Figure 15 shows the increasing amount of operational energy used by buildings as they get older, (Straube, 2009).Because of his interest in 'going green', Wyatt is hoping to make the Printer's Building an icon for the use of green technologies in older buildings in Worcester.

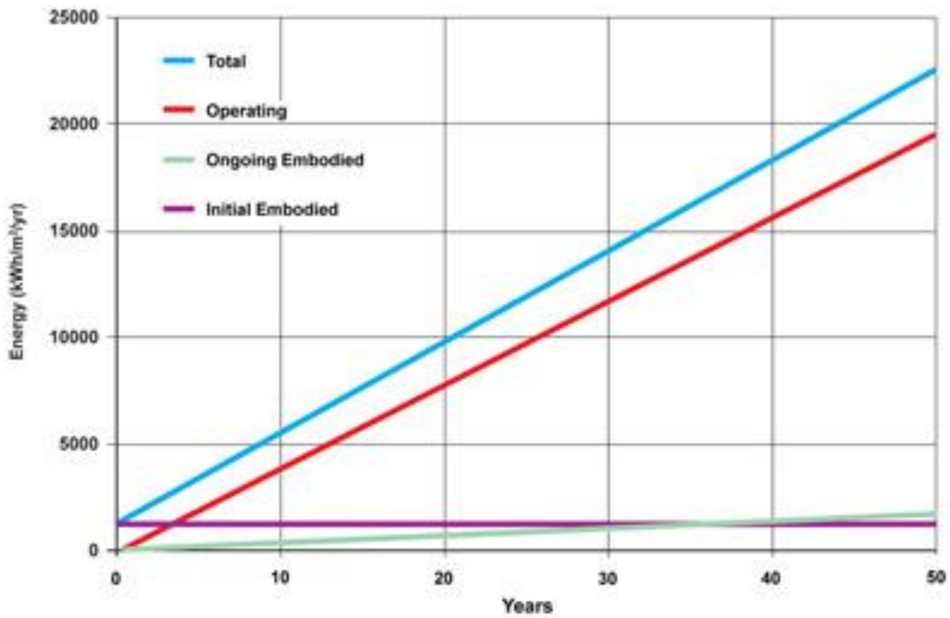
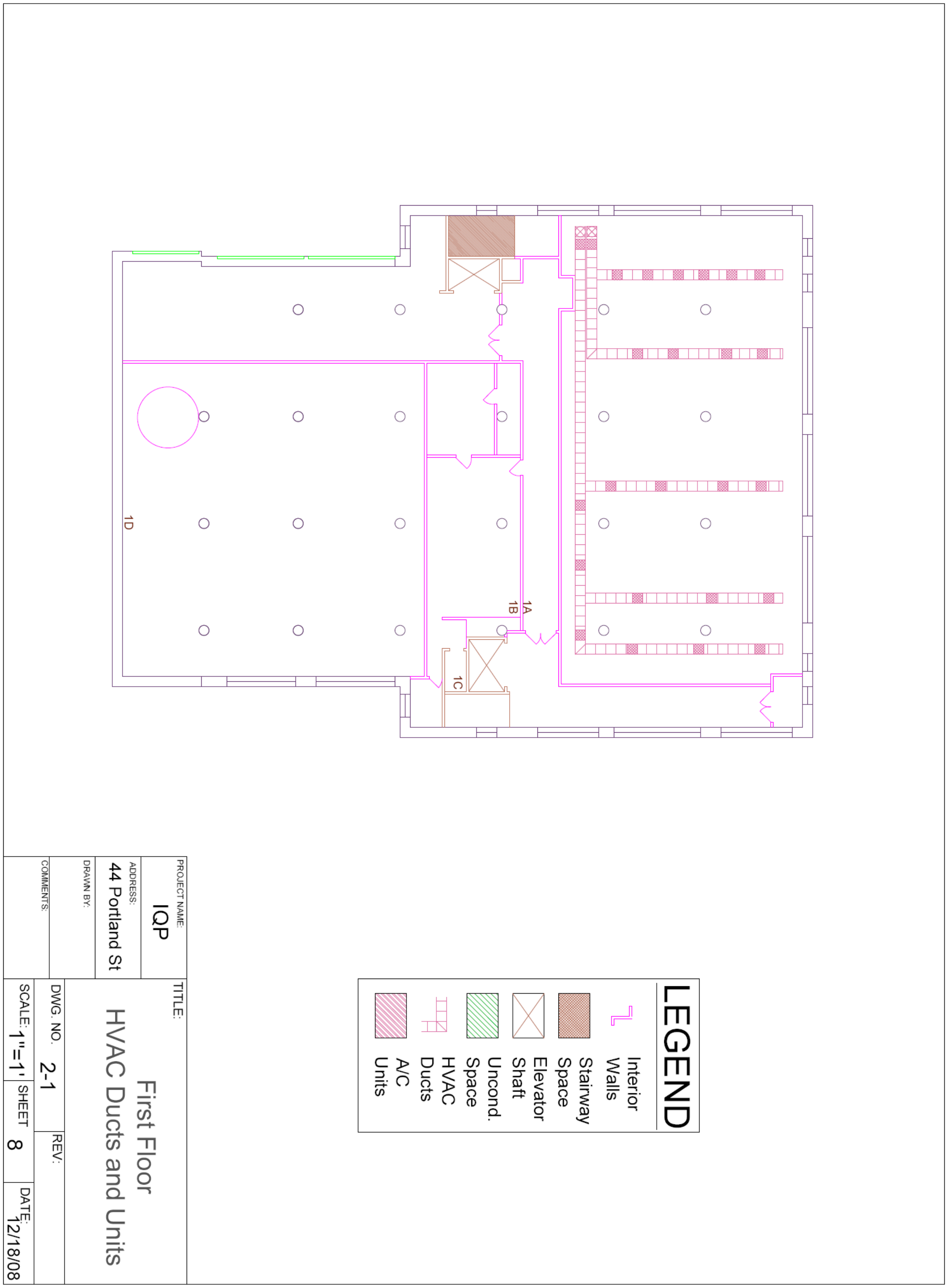
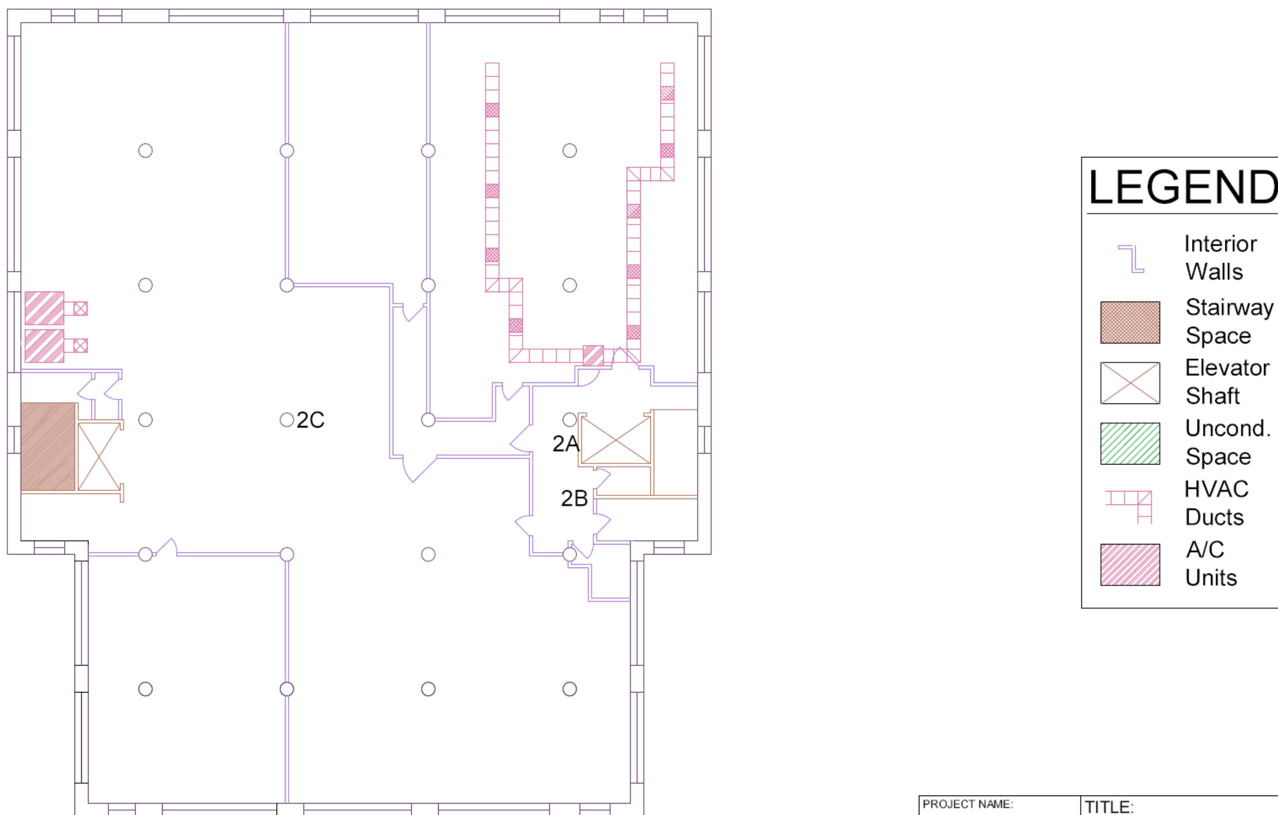


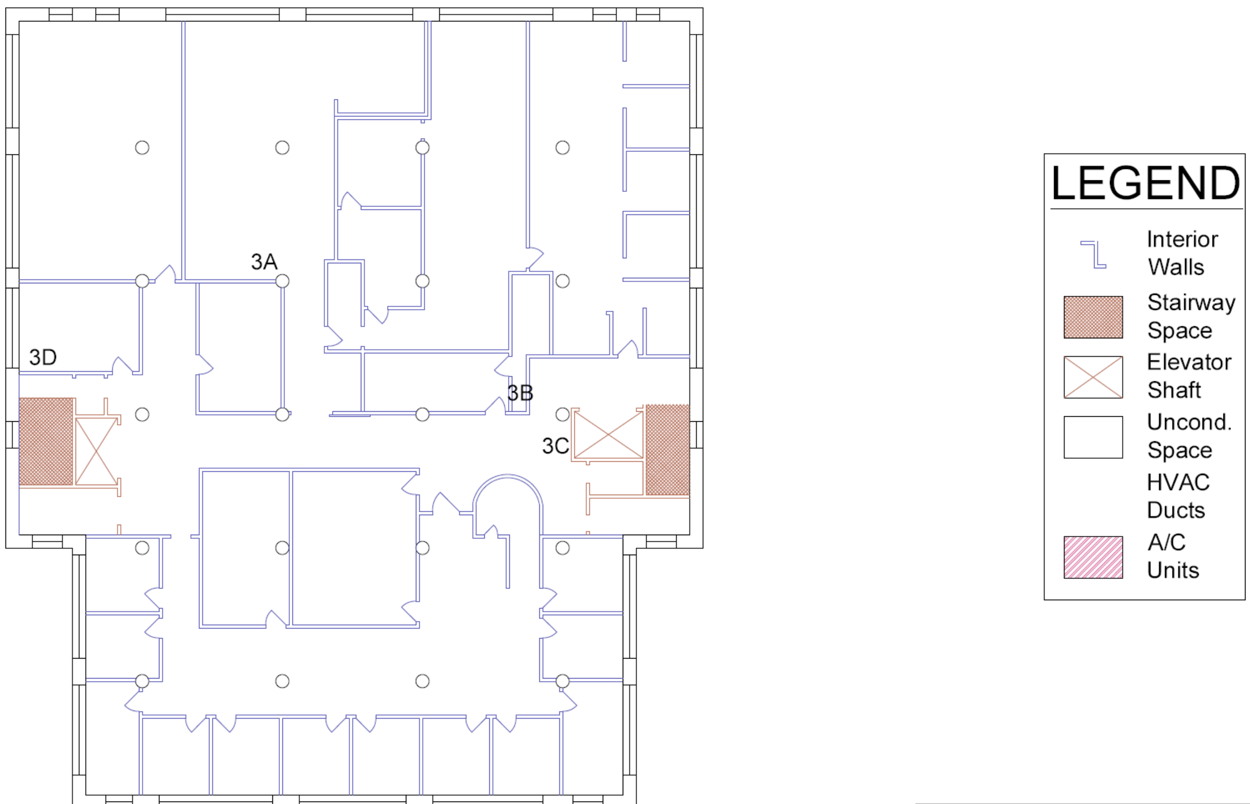
Figure 27: Energy Usage by Building Age (in kWh/m2/yr) (Straube, 2009)

Appendix C: CAD Drawings

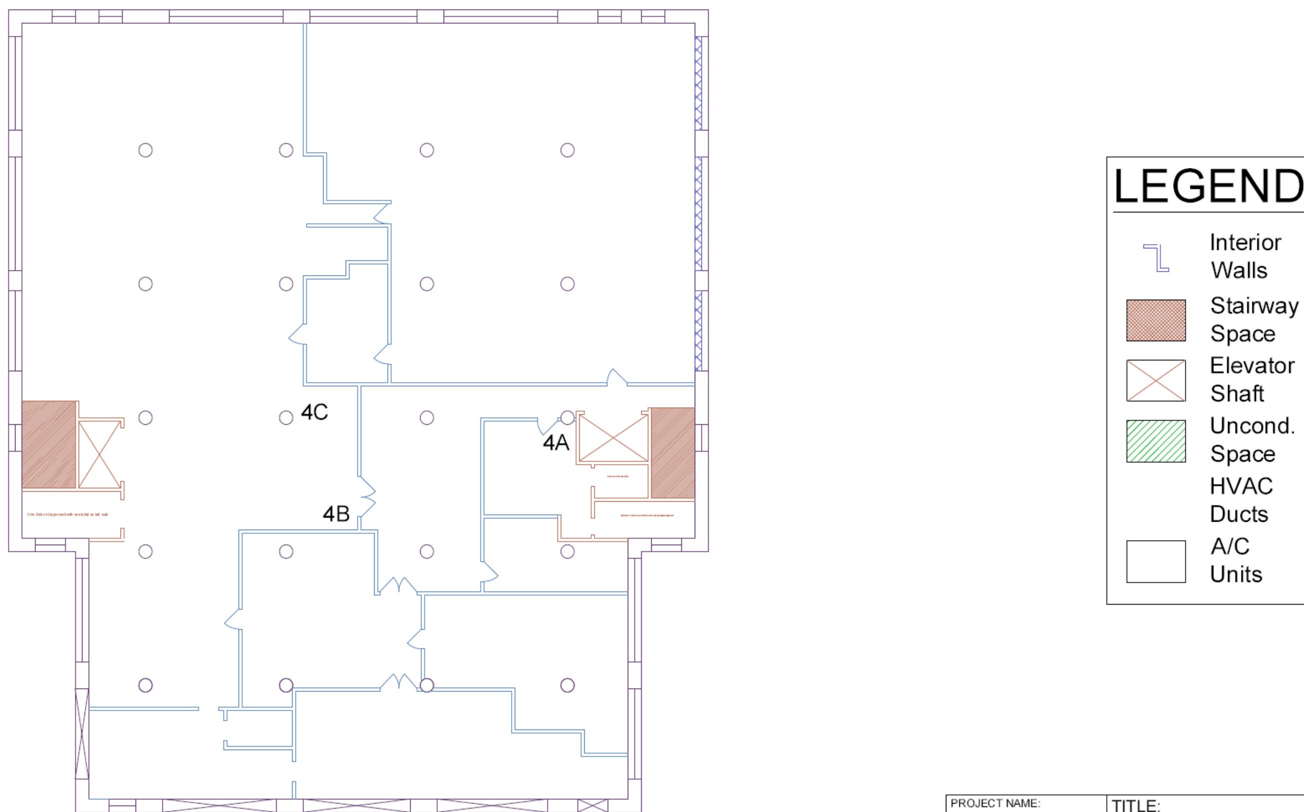




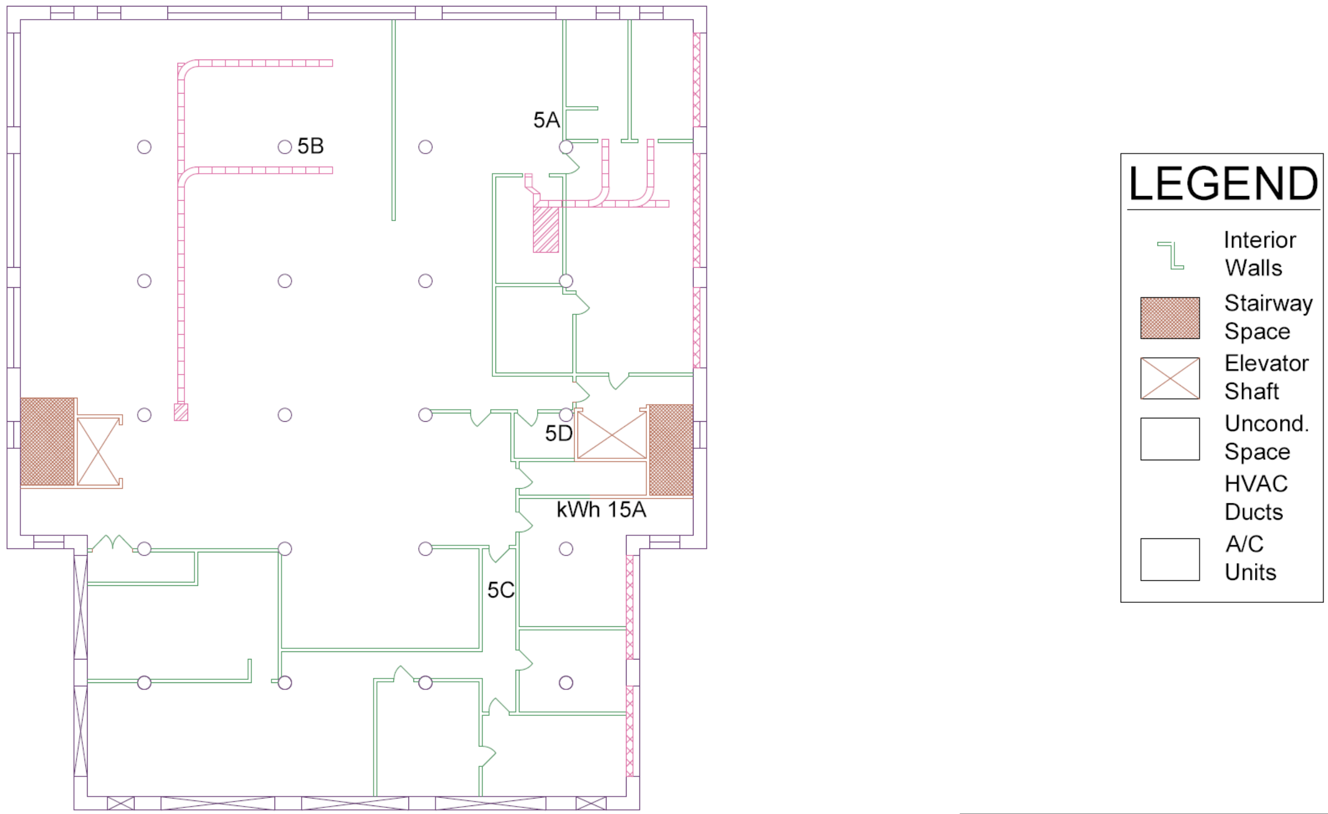
PROJECT NAME: IQP	TITLE: Second Floor HVAC Ducts and Units		
ADDRESS: 44 Portland St			
DRAWN BY:	DWG. NO. 2-2	REV:	
COMMENTS:	SCALE: 1"=1'	SHEET 9	DATE: 12/18/08



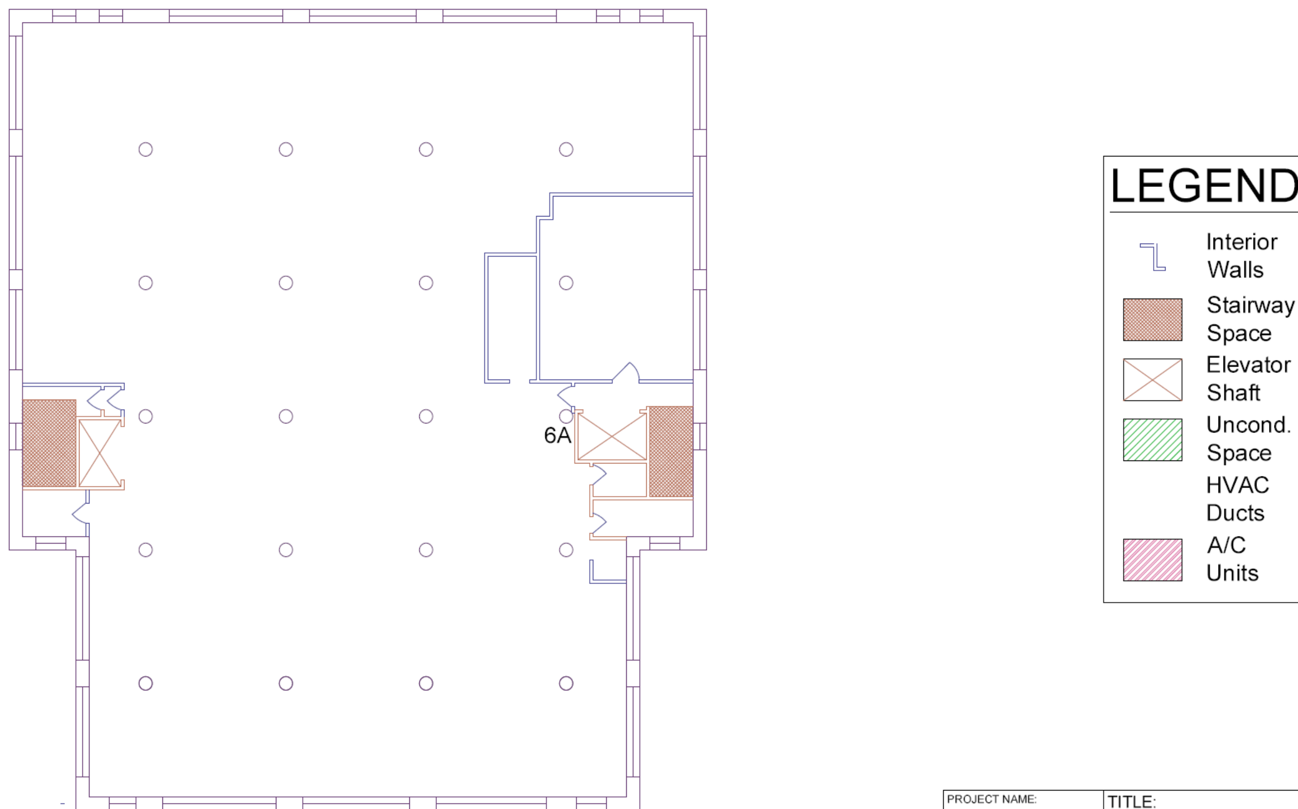
PROJECT NAME: IQP	TITLE: Third Floor Unconditioned Space		
ADDRESS: 44 Portland St			
DRAWN BY:	DWG. NO. 3-3	REV:	
COMMENTS:	SCALE: 1"=1'	SHEET 17	DATE: 12/18/08



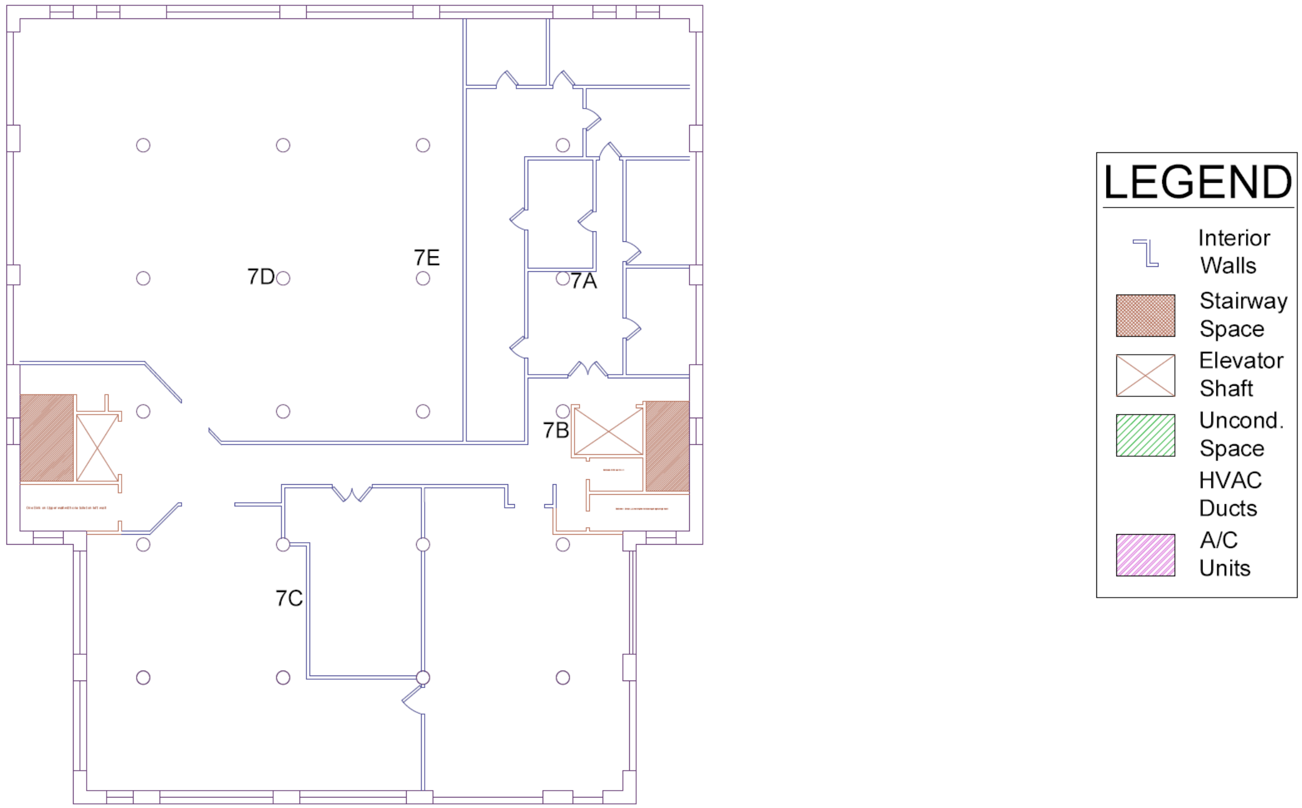
PROJECT NAME: IQP	TITLE: Fourth Floor Unconditioned Space	
ADDRESS: 44 Portland St		
DRAWN BY:	DWG. NO. 3-4	REV:
COMMENTS:	SCALE: 1"=1'	SHEET 18	DATE: 12/18/08



PROJECT NAME: IQP	TITLE: Fifth Floor
ADDRESS: 44 Portland St	
DRAWN BY:	DWG. NO. 1-5 — REV:
COMMENTS:	SCALE: 1"=1' — SHEET 19 — DATE: 12/18/08



PROJECT NAME: IQP	TITLE: Sixth Floor Unconditioned Space		
ADDRESS: 44 Portland St			
DRAWN BY:	DWG. NO. 3-6	REV:	
COMMENTS:	SCALE: 1"=1'	SHEET 20	DATE: 12/18/08



PROJECT NAME: IQP	TITLE: Seventh Floor			
ADDRESS: 44 Portland St				
DRAWN BY:				
COMMENTS:	DWG. NO. 2-7		REV:	
	SCALE: 1"=1'	SHEET 14		DATE: 12/18/08

Appendix D: Circuit Breaker Maps

1A #9 KWH METER

1B

1	20	2	20
3	20	4	20
5	20	6	20
7	20	8	-
9	-	10	20
11	30	12	-
13	-	14	30
15	20	16	-
17	20	18	40
19	20	20	-

1C WICN 7 KWH METER

1D

20	20
20	20

1Ea MAIN 100

23	20	24	20
25	20	26	20
27	20	28	20
29	20	30	20
31	20	32	20
33	20	34	20
35	20	36	20
37	20	38	20
39	20	40	40
41	20	42	40

1Eb

1	-	2	20
3	15	4	20
5	15	6	15
7	15	8	15
9	20	10	30
11	20	12	30
13	70	14	45
15	70	16	45

17	70	18	45
19	50	20	15
21	50	22	15
23	50	24	15

1Ec main 100

13	20	12	20
15	20	14	20
17	20	16	20
19	20	18	20
21	20	20	20
23	20	22	20
25	20	24	20
27	20	26	20
29	20	28	20
		30	20

1Ed main 100

1	20	2	20
3	20	4	20
5	20	6	20
7	20	8	20
9	20	10	20
11	20	12	20
13	20	14	20
15	20	16	20
17	20	18	20
19	20	20	20
21	20	22	30
23	20	24	30
25	20	26	20

2A #11 KwH Meter

1	2x20	2	20
3	2x20	4	20
5	20	6	15
7	20	8	15
9	20	10	15
11	20	12	2x20
13	2x20	14	2x20
15	2x20	16	20

17	30	18	20
19	30	20	20

2B #10 kwH meter

2C

1	20	2	20
3	20	4	20
5	20	6	20
7	20	8	20
9	20	10	20
11	20	12	20
13	20	14	20
15	20	16	20
17	20	18	20
19	20	20	20
21	20	22	20
23	20	24	20
25	20	26	20
27	30	28	40
29	30	30	40
31	50	32	20
33	50	34	20
35	50	36	20
37	20	38	20
39	20	40	20
41	20	42	20

3A

3B

B3

20	20	20

20	20	20

A3

1	50	2	50
3	50	4	50
5	50	6	50
7	20	8	20
9	20	10	20
11	20	12	20
13	30	14	20
15	30	16	20
17	20	18	20
19	20	20	40
21	60	22	40
23	60	24	20

3C #13 KWH METER

3D

Panel a

1	20	2	20
3	20	4	20
5	20	6	20
7	20	8	20
9	20	10	20
11	20	12	20
13	20	14	20
15	20	16	20
17	20	18	20
19	20	20	20
21	20	22	20
23	20	24	20
25	20	26	20
27	20	28	20
29	20	30	20

Panel B

1	20	2	15
3	20	4	15
5	20	6	15
7	20	8	20
9	20	10	20
11	20	12	20
13	20	14	2

15	20	16	20
17	20	18	20
19	20	20	20
21	20	22	30
23	20	24	20
25	-	26	20
27	60	28	15
29	-	30	-

Panel C

1	2x20	2	20
3	2x20	4	20
5	2x20	6	20
7	2x20	8	20

3d

Panel f3r

	100	70
-		
	100	70
		100

4A # 14 kwh meter

4A1

1	20	2	20
3	20	4	30
5	-	6	-
7	20	8	20
9	20	10	20
11	20	12	20

4A2

1	20	16	20
2	2x20	17	20
3	20	18	20
4	20	19	20
5	20	20	20
6	20	21	20
7	20	22	20

8	20	23	20
9	20	24	20
10	20	25	20
11	20	26	20
12	20	27	20
13	20	28	20
14	20	29	20
15	20	30	20

4A3

1	20	3	20
2	20	4	20
7	20	5	20
6	20	8	20
	20	10	30
	20	12	20

4A4

[redacted]

4B

1	30	2	40
3	30	4	40
5	30	6	30
7	30	8	30
9	30	10	20
11	30	12	20
13	30	14	20
15	40	16	20
17	40	18	15
19	30	20	20
21	20	22	20
23	30	24	20
25	30	26	20
27	20	28	20

29	20	30	20

4C

1	20
2	20
3	30
4	15
5	15
6	15
7	15
8	15
9	15
10	20
11	20

Master 100

5A

Panel 3

	1		2	2x40	XXXXX
XXXXX	3	3x20	4		
	5		6	2x20	XXXXX
	7	2x20	8		
	9		10	2x60	XXXXX
	11	15	12		
	13	20	14	20	
	15	20	16	20	
Lighting-Shop	17	15	18	20	
XXXXX	19	20	20	2x20	Air Handler
XXXXX	21	40	22		
XXXXX	23	2x20	24		
	25		26	3x50	A/C
			28		

Panel 4

XXXXX	1	20	2	20	XXXXX
XXXXX	3	20	4	20	XXXXX
XXXXX	5	20	6		
Outlets-Shop	7	20	8	3x30	Machine
XXXXX	9		10		
	11	3x30	12	3x20	Machine

	13		14		
XXXXX	15	20	16		
XXXXX	17	20	18	20	Machine

5B

PI

Machine	1	60	2	30	Machine
Machine	3	40	4	20	Machine
Machine	5	30	6	60	Machine
Outlets-Shop	7	20	8	20	Machine

P2

	1		2	-	
	3		4	80	Machine
	5		6	-	
Machine	7	20	8	-	
Machine	9	20	10	50	Machine
Machine	11	20	12	-	
Machine	13	20	14	20	Machine
Machine	15	20	16	-	
	17	-	18	20	Machine
Machine	19	60	20	20	Machine

5Cb

			8	20	Outlets-CPU room
			10	20	
			12	2x30	
			14		
			16	15	
	17		18	15	
Machine	19	3x30	20	20	Outlets-Empty room
	21		22	20	
	23		24	2x20	XXXXX?
Machine	25	3x50	26		
	27		28	2x50	
Outlets-shop	29	20	30		
	31	20	32		
A/C	33	2x20	34	3x20	XXXXX?
	35		36		
Machine	37	3x30	38	15	Outlets-Bathroom
	39		40	20	

	41		42	20	Lighting-Shop

5Ca #15a kwh meter

	1		2		
Air Handler	3	3x20	4	3x70	Log Eline Processor
	5		6		
Lighting-Shop	7	2x30	8	2x20	Lighting-Shop
	9		10		
Outlets-Photo Room/Air Handler	11	20	12	20	Outlets-CPU Room
Outlets-Camera Room	13	20	14	20	Outlets-CPU Room
Lighting-Shop	15	20	16	20	Outlets-CPU Room
Outlets-Shop	17	20	18	20	Outlets-Photo Room
Exhaust Fan	19	20	20	20	Lighting/Outlets-Photo Room
Lighting-Shop	21	20	22	20	Lighting-Photo Room
Outlets-Shop	23	20	24	20	Lighting/Outlets-Photo Room
Outlets-Shop	25	20	26	20	Lighting-Photo Room
Outlets-Shop	27	20	28	20	Outlets-Photo Room
Outlets-Shop	29	20	30	20	Outlets-Shop
Outlets-Empty Room	31	20	32	20	Outlets-Shop
Damper	33	20	34	20	Outlets-Shop
A/C	35	2x30	36	2x20	Vent Fan
	37		38		
Camera	39	2x60	40	2x40	Plate Processor
	41		42		

5Da

	1	20	2	20	
	3	20	4	20	
	5	20	6	20	
	7	20	8	20	Outlets-Shop
	9	20	10	20	
	11	20	12	20	
	13	20	14	20	
	15	20	16	20	
Lighting/Outlets-Bathroom	17	20	18	20	
	19	20	20	20	
	21	20	22	20	
	23	20	24	20	

5Db

	1	20	2	20	

	3	20	4	20	Lighting/Outlets-Shop
	5	30	6	20	Lighting/Outlets-Shop
Lighting-Shop	7	20	8	20	
Lighting-Shop	9	20	10	20	
Lighting-Shop	11	20	12	20	Lighting-Shop
Lighting-Office/Outlets-Office/Shop	13	20	14	20	Lighting-Bathroom
	15	15	16	20	
Outlets-Shop	17	20	18	20	Outlets-Closet
Lighting-Shop	19	20	20	20	

5Dc

5Dd

A/C	1	3x30	2	2x20	A/C
	3		4		
	5		6	20	Outlets-Roof

5De

1	2	3	4	5
20	20	20	20	20
Outlets-Office	Outlets-Office		Outlets-Office	Outlets-Office

5E

Panel 5

Machine	1	2x15
	2	
Machine	3	2x20
	4	

6A

1	20	2	2x30
3	20	4	2x30
5	20	6	20
7	2x20	8	20
9	2x20	10	2x20
11	20	12	2x20

6A2

1	20	2	20
3	20	4	20
5	20	6	20
7	20	8	20
9	20	10	20
11	20	12	20
13	20	14	20
15	70	16	20
17	70	18	20
19	70	20	20

6A3

7A

1	20	2	20
3	20	4	20
5	20	6	20
7	20	8	20
9	2x30	10	20
11	2x30	12	20
13	2x30	14	20
15	2x30	16	20
17	2x30	18	2x20
19	2x30	20	2x20

21	2x30	24	2x20
23	2x30	26	20
25	20	28	20
27	20	30	20
29	20	32	20
31	20	34	20
33	20	36	20
35	20	38	-

7B #18 kwH meter

1	30	2		
3	30	4		
5	30	6	100	Main
7	20	8	20	
9	20	10	20	
11	20	12	20	
13	-	14	20	
15	20	16	20	
17	20	18	20	
19	20	20	20	

7C

1	-	2	15
3	30	4	15
5	-	6	15
7	30	8	15
9	15	10	15
11	-	12	15
13	50	14	15
15	20	16	20
17	20	18	20
19	20	20	20
21	20	22	20
23	20	24	20
25	20		
27	-	main	200

7D

1	15	2	15
3	15	4	15
5	15	6	20
7	15	8	15

9	15	10	15
11	15	12	15
13	15	14	15
15	20	16	15
17	15	18	15

7E Cp-15

1	20	2	20
3	20	4	20
5	20	6	20
7	20	8	20
9	20	10	20
11	20	12	20
13	20	14	20
15	20	16	20
17	20	18	20
19	20	20	20

cp-1

1	20	22	30
2	20	23	30
3	20	24	60
4	30	25	60
5	30	26	60
6	30	27	60
7	30	28	20
8	20	29	20
9	20	30	20
10	20	31	20
11	20	32	40
12	30	33	40
13	30	34	40
14	60	35	50
15	60	36	50
16	60	37	50
17	50	38	50
18	50	39	50
19	50	40	50
20	30	41	15
21	30	42	20

Basement A Kwh Meters 3-6

Main building power

60	20	20	20

Building Lights 1

20	20
20	20

Building Lights 2

20	x
x	20
20	20
20	20

Well Serve Inc.

20	15
30	20

Fuse Panel

20	25
20	20

Loading Dock

15	20
30	30