AIDS PROJECT WORCESTER:
REDUCING ENERGY COSTS, GIVING BACK TO THE COMMUNITY

Interactive Qualifying Project submitted completed in partial fulfillment

of the Bachelor of Science degree at

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Submitted to:

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Abstract

Since 1987, AIDS Project Worcester (APW) has been devoted to providing non-medical service to the Worcester community for those directly and indirectly affected by HIV/AIDS. Their client-base has increased by 15% annually and the demand for funding has become even greater. To help with that issue our project goal was to assess the AIDS Project Worcester's facility and operations and produce technological and behavioral recommendations to help them lower their energy costs over short, medium and long terms.

To do this, we performed energy and behavioral audits of the building and staff. We found that APW can save ~24% (or ~$10,000) of their annual energy costs by following our recommendations for technology upgrades and policy changes.

Executive Summary

AIDS Project Worcester (APW) has been faithfully serving the Worcester community since 1987. They provide non-medical assistance to people who are directly or indirectly affected by HIV/AIDS. They centralize their mission around three core values; education, advocacy, and service. Considering the poor performance of the economy and a client base that increases by 15% every year, they targeted their high energy costs as a potential area for savings.

To help APW determine if their energy costs could be lowered, we tasked ourselves with evaluating the building's energy use and recommending ways to reduce consumption. Our Interactive Qualifying Project's goal was to assess the AIDS Project Worcester's facility and operations and produce technological and behavioral recommendations to lower energy costs over short, medium and long terms.

Methodology Overview

In order to identify and offer solutions to the issues with this building we first devised steps to complete the tasks necessary to successfully analyze APW's building energy use. Our first step was to conduct a three-part energy audit. The first was a "walkthrough" inspection, during which we visually inspected various energy-related building characteristics. For the second part of the audit, we evaluated the HVAC systems by using temperature-recording sensors to monitor the operation of the HVAC units for eight consecutive days. Lastly, we used a thermal camera to inspect the building envelope for thermal leaks and insulation problems.

The next step was a behavioral audit. This audit observed computer use, programmable thermostat settings, and other behavior-related energy consumption characteristics. To observe these things our group visited APW after working hours to check what was left on in the offices. We recorded the power used by computers, monitors, desk lamps, and space heaters and checked to see if any lights were left on.

The last step to our methodology was to synthesize short, medium and long term recommendations for implementation at APW. For our short-term recommendations, we compiled behavioral or policy change suggestions that cost little to no money. Our medium- and long-term recommendations composed a sequence of technological upgrades and additions that we determined were appropriate for APW and would solve the problems that we identified in our energy audit.

Findings Overview

Through our methodology we came to several conclusions about the energy usage of APW. These findings are separated into short, medium and long terms along with their recommendations.

Short term:

We found that there were eight space heaters being used by the staff of APW. Each of these space heaters can consume 1400 W of energy, which can amount to approximately $105 in electricity costs annually. We estimated that eight space heaters cost roughly $840 annually. The next thing we found was that all 31 computers in the APW building were left on when not in use and during non-working hours, time which accounts for 60% of the total cost of running the computers. We estimate that changing policy to allow or require staff members to shut down their computers would save APW over $2000 annually. The last thing we noticed was that hallway lights were left on all day and night as well. Having these lights turned off at the end of the working day can save APW approximately $588 annually.

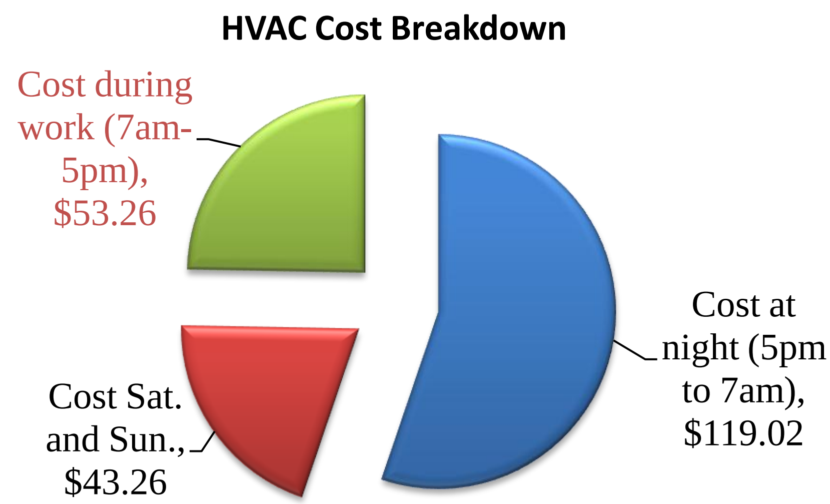
Our recommendations for our short term findings include:

- Shutting down computers at the end of the day
- Temporarily promote wearing sweaters to reduce space heater use
- Use a "Wake-on-LAN" feature that allows remote access for specific staff members that need to access their work computers from home
- Using timers on space heaters
- Turn off the lights at the end of the day or use timers or motion sensors

Medium term:

We found that the HVAC systems were operating inefficiently. The HVAC systems were also working more often at night when the building was not being used than they were during the day. They were using energy that was not needed as there were no staff members in the building.

The four rooftop units were found to use roughly 75% of their energy during non-working hours and weekends.



We found that by upgrading to programmable thermostats APW can reduce energy costs by roughly 60% and save approximately $1800 annually. This estimate could prove to be low because our projection did not include air-conditioning operation in the summer. If the AC operated in similar fashion to the heating units, estimated savings would conceivably double.

We also found that the building envelope was compromised. The thermal camera was able to show us hot-spots in many areas of the roof as well as the emergency exit door going to outside and the main entrance door. We also looked into funding for these types of improvement. We found that NSTAR offers an arrangement as they will evaluate the HVAC systems for efficiency and make recommendations. If these recommendations are followed through with then they will reimburse the cost of the evaluation. Also, we found it would be beneficial to contact the building owner to have the HVAC systems checked for maintenance and to replace the roof to fix leaks and insulation.

Our recommendations for medium term findings include:

- Regulating access to thermostats so that they cannot be tampered with
- Replace existing thermostats with programmable ones such at Net/X which can be wirelessly controlled to regulate temperatures in the building

- Test the HVAC for efficiency to help with any inefficiencies
- Replace the roof will help to add insulation and can prepare for capital improvements i.e. solar panels and green roof
- Weather stripping the doors

Long term:

Finally our long term recommendations will be to install capital improvements on the rooftop of the building itself. One such improvement will be to install a green roof. We found that by installing a green roof it will provide additional insulation and waterproofing, storm water run-off management, and it can increase efficiency of solar panels because it reduces ambient temperatures.

Another capital improvement we looked into was the installation of solar panels. We had Sunlight Solar, a local solar installer, perform an evaluation of the APW building for a solar power generation installation. After their inspection they sent us an analysis of their findings which included costs, payback period and efficiency. Installing the solar panels could provide APW with 12% of its total power usage and pay itself back in 5-7 years. The solar panels work well in conjunction with green roofs and some funding options for these improvements include Massachusetts Technology Collaborative and a Federal Tax credit that can reduce the cost of solar panels by 55%. The Home Depot Foundation and Green Communities Grant offer money towards "green" construction items and projects.

Our recommendations for long term findings include:

- Contacting a structural engineer to examine roof to see what improvements are needed for capital installations
- Make a capital improvement such as adding a green roof or installing solar panels

The recommendations that we have made offer a wide range of energy cost-reduction measures, from quick, easy policy changes to major building upgrades costing over $20,000. However, the first real step before any of these recommendations is to spread the energy conservation awareness to the staff members of APW. To do this we gathered examples of popular energy-awareness posters and displayed them in the hallways for the staff to comment on at their leisure using provided post-it notes. We used these comments to select the ones that the staff responded most favorably to, and provided APW with the location for purchasing them to initiate an energy-conservation awareness campaign within the walls of APW. We did this to be the starting block for APW to move forward in becoming a greener, more energy efficient organization.

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Chapter 1: Introduction

A poor economy is a phenomenon that touches everyone, from the rich to the poor, from big business to small. Caught squarely in the middle of these effects are servants to the community; organizations that depend on the donations of others in order to be able to offer crucial services. When funding for these organizations becomes tight, there may be no other option than to reexamine internally to see where cuts can be made, which could mean downsizing their capacity for service.

One such organization, AIDS Project Worcester, was looking to expand the community that they serve even in the face of economic stagnation. This speaks of the dedication and passion that they have for providing unique, personal counseling and aid services to a marginalized portion of the community: those who are diagnosed with or in some way affected by HIV/AIDS. This portion of the community continues to grow and rely on APW for service; they have seen their client base grow by 15% per year for over a decade, and now serve over 5000 people annually. While their spirit may not have been affected by the poor economy, their funding was. They realized that in order to continue expanding their services they would have to increase the amount they could do with their current level of funding.

This realization prompted Director Joe McKee and (her position) Martha Akstin to examine their operating energy costs (which they found to be high at roughly $40,000 for 2009 alone). Their energy costs have effectively doubled since 2004, even though their building footprint has remained the same. Realizing how much of their funding was going towards the energy costs of their facility, which they have used since 1987, gave them the idea that perhaps energy use could be made more efficient. This would make it possible to reassign a significant portion of that money to service opportunities.

The goal of our project was to conduct physical and behavioral audits of the APW office so that we could produce recommendations to help them lower their energy costs. Both physical and behavioral audits are critical. This is because of the two aspects of energy use and how they interact: human behavior and building system efficiency. APW's goal of saving money is not exclusive to either of these ideas; that is why this project focused on both of them in order to maximize the potential for savings. A building that uses incandescent bulbs for its lighting costs more money to operate than it should even if the people in that building always remember to turn them off when they leave the rooms. Likewise, a building that uses state-of-the-art low-power LED lighting costs more money to run than it should if the people in that building never turn the lights off when they leave. Saving money on energy is reliant on combining efficient building systems and features with economical and energy-conserving operational behavior.

We accomplished this by completing five objectives. First, we gauged the building systems' energy use against industry-developed standards for energy efficiency. This process is called an energy audit, and we used various tools to collect data, analyze it, and make informed recommendations for building improvement. Second, we conducted a behavioral assessment which examined the energy use habits of the staff. Third, we made technological and behavioral recommendations to APW organized over a relative timeline of short, medium, and long term goals. Then we examined funding sources for our recommendations and made a comprehensive list of requirements for qualification. Finally, as a jumpstart to an energy conservation awareness campaign, we collected feedback from the staff on various conservation posters and delivered the highest-ranked ones to APW to display in their hallways and offices.

The report unfolds as follows. Chapter two provides a detailed overview of background material pertinent to our study and forms the basis for the aforementioned five project objectives. In Chapter three, those five objectives are further discussed to compose the methodology section, which covers the specifics of what we did while on site at APW. Chapter four presents our findings alongside our recommendations, beginning with short-term ones and finishing with the long-term. Chapter five contains our analysis of funding availability for the measures we recommend, and we finalize our report in chapter six with our concluding statements.

Chapter 2: Background

This section discusses the background of our project. We introduce different approaches to green construction, green building technologies, energy auditing, and energy conservation education. More importantly, our discussion frames these topics in reference to our project by connecting these various approaches to APW and their particular building and determining if they are appropriate. This research formed the specific objectives and desired outcomes of this project.

2.1 Approaches to "Green"

Rising energy costs coupled with technological advancements in energy efficiency have made implementation of green[1] technology in both new and old buildings economically feasible. As a result, standards for green buildings have been developed by various agencies. This section examines the approaches of two popular examples of these standards, LEED and Energy Star, and their requirements to certify a building as "green." These standards are important because they are currently the basic guidelines leading the construction industry. These two approaches ground our assessment and evaluation process in nationally-recognized green standards.

Currently, the most popular green design framework in the US is Leadership in Energy and Environmental Design (LEED). LEED was established by the U.S. Green Building Council, an organization that actively fosters more energy efficient buildings. LEED is a complete set of guidelines for the construction, renovation, maintenance, and operation of green buildings. These guidelines are organized depending on the construction at hand. For instance, there are two different sets of LEED guidelines for new constructions and existing buildings.

First and foremost LEED provides an evaluation tool that can be used to systematically plan and realize a greener building. The LEED evaluation system, in particular, seeks to encourage and accelerate "global adoption of sustainable green building and development

[1] The word "Green" is used to define an ideal that encompasses more than just lowering energy bills. Green is not solely supportive of energy efficiency; it is also concerned with reducing environmental impact and integrating people and structures into a more natural and healthy environment. Even though in many cases the environment is the primary concern for the green ideal, it does focus heavily on reducing dependence on fossil fuels by lowering the demands of energy consumers, whether they are buildings or humans. Therefore our goal of reducing energy costs for APW and the green goal of making society and industry environmentally friendly are strongly linked and in some cases hereafter we discuss these ideas interchangeably.

practices through the creation and implementation of universally accepted tools and performance criteria" by offering a rating system to the green industry that is "voluntary, consensus-based, and market-driven" (www.usgbc.org).

The LEED rating system takes into account current and proven technologies and, based on that, composes standards for "a green building in design, construction, and operation" (www.usgbc.org). There are a certain number of points in each category which are summed to determine a building's "score." The value of this score determines if the building is considered LEED certified, and different ranges of values correspond to different levels of LEED certification. LEED's rating system for existing buildings in "Operations & Maintenance" has the following categories:

- Sustainable Sites (SS)
- Water Efficiency (WE)
- Energy and Atmosphere (EA)
- Materials and Resources (MR)
- Indoor Environmental Quality (IEQ)
- Innovation in Operations (IO)
- Regional Priority (RP) (www.usgbc.org)

The operation and maintenance guide is a list of very detailed and very specific criteria that can be used to evaluate the existing building as a LEED certified building. The following table shows the categories and some of the criteria under them.

Sustainable Site
Building Exterior and Hardscape Management
Light Pollution Reduction
Water Efficiency
Prerequisite: Minimum Indoor Plumbing Fixture and Fitting Efficiency
Cooling Tower Water Management
Energy and Atmosphere
Prerequisite: Energy Efficiency Best Management Practices: Planning,

Documentation and Opportunity Assessment
Optimize Energy Efficiency Performance
Materials & Resources
Prerequisite: Sustainable Purchasing Policy
Solid Waste Management: Facility Alterations & Additions
Indoor Environmental Quality
Prerequisite: Outdoor Air Introduction & Exhaust Systems
Prerequisite: Green Cleaning Policy
Innovation In Operations
Innovation in Operations
Documenting Sustainable Building Cost Impacts

The above checklist is only part of an extensive, comprehensive list. Implementing all these criteria will improve the energy efficiency of a building but practicality and appropriateness are also factors in this implementation. Thus, we look at the checklist not as a guideline but as a reference for our project.

The Operations & Maintenance checklist specifies what has to be done in each category in order to obtain a certain number of points. This specific process is designed with "the intent to promote high-performance, healthful, durable, affordable, and environmentally sound practices in existing buildings" (www.usgbc.org). This checklist offers insight into potential building performance issues and the values assigned to specific items can help determine a relative scale of importance or urgency.

Another form of green certification is the U.S. Environmental Protection Agency's (EPA) guidelines for assessing, constructing, and renovation green homes, called Energy Star. Homes that meet the EPA's green home requirement receive Energy Star certification. According to the EPA, an Energy Star home should have the following features:

- An Efficient Building Envelope - with effective levels of wall, floor, and attic insulation properly installed, comprehensive air barrier details, and high performance windows;
- Efficient Air Distribution - where ducts are installed with minimum leakage and effectively insulated;

- Efficient Equipment - for heating, cooling, and water heating;
- Efficient Lighting - including fixtures that earn the Energy Star label
- Efficient Appliances - including Energy Star-qualified dishwashers, refrigerators, and washing machines among other appliances (www.energystar.gov)

We view these green standards as references for our building assessment process rather than as a rule for the completion of the project. We considered major aspects of green building defined by LEED and ENERGY STAR but we did not adhere to every detail in those standards because bringing APW into line with them proved to be costly and many aspects of the standards are aimed at reducing the adverse environmental impact of a building and not on saving money. For example, LEED contains guidelines for "system-level metering," a "custodial effectiveness assessment," and "storm water quantity and erosion control." For a pre-1950 structure like APW's building, attempting to implement many of these things would be massive undertakings and would require resource- and time-intensive modifications that may not even save APW money at all.

In this section, we discussed LEED and Energy Star, two leading green standards. We conclude that while green standards do offer excellent guidelines for environmental friendliness, we found them lacking when we tried to apply them to APW and our ultimate goal of reducing energy costs in an existing building.

2.2 Energy Auditing

APW's building was constructed before 1950 and was last renovated in 1985. The building has systems in place like HVAC, lighting, and insulation whose efficiencies and operating conditions determine how much energy is used to operate the building. Efficient systems can make for an efficient building, but with older structures like APW the efficiency or condition of their systems over 20 years after their installation is unknown. Determining the efficiency and condition of building characteristics like these is known as energy auditing.

In recent years, energy auditing has been the subject of significant amounts of research and development by various institutions and is widely recognized as the logical first step in making a building more efficient. It can be done at any stage of a building's life, even before the building is complete. Energy auditing enables a person or team to evaluate a building and locate where its inefficiencies are. This section examines the energy audit process conceptually from three different perspectives. Through an evaluation of these different yet complementary approaches, we identified an appropriate process to carry out during our project.

There are three levels of audits. The first is a walkthrough, which is centered on a checklist and is completed by walking through a building and visually inspecting it. The second, a standard audit, is more involved. In addition to a visual inspection, the auditor uses specialized tools, such as thermal-imaging cameras to make measurements and record data. Using these tools, he can perform a specific, quantitative analysis of specific building characteristics such as the building envelope and HVAC systems. This allows the auditor to more accurately calculate how energy is being used. The third level is the construction of a computerized model of the building to very accurately analyze building performance. Computer modeling is the most detailed and accurate form of auditing, but it is also the most expensive because of the time associated with accurately creating the building in a virtual computer environment. A professional energy auditor could spend over a month to virtually model a building.

The walk-through or "level 1" audit is the simplest form of auditing. We used two primary sources, The Handbook of Energy Audits and Washington State University's Energy Program: Energy Audit Workbook, to research this level of auditing. These two sources laid out instructions for performing a level 1 audit. Here are the categories for inspection provided by the WSU Energy Audit Workbook checklist along with some examples taken from each:

- Building envelope
    - Blinds and curtains are used to help insulate the building. (Y/N)
- Building occupancy
    - Off-hour activities extend operating hours for energy using systems. (Y/N)
- HVAC-control settings
    - Thermostats on heating/cooling units are vulnerable to occupant adjustment. (Y/N)
    - Control devices are not inspected on a regular basis. (Y/N)
    - Building temperatures are not adjusted for unoccupied periods. (Y/N)
- Lighting usage
    - Lamps and fixtures are not clean. (Y/N)
    - Lighting is on in unoccupied areas. (Y/N)

- Power consumption
    - Substantial electricity demand charges are incurred. (Y/N)

This list is designed to be completed by visual inspection. For example, examining thermostat programming does not require any tools or preparation. This quality makes performing this level of audit accessible and attractive to a wide audience.

The “standard” or “level 2” audit is a more involved process in which the auditor uses specialized tools and tests to quantitatively analyze the building. Some of these tests and tools include a combustion zone test, which is used to measure the efficiency of the HVAC units and the pressure of the flow though the ductwork, and a door-blower, which pressurizes the air in the building to determine where thermal leaks may be (Thuman, 1998). Also, many level 2 audits utilize thermal cameras to inspect building insulation. A thermal camera “sees” heat, which makes it an effective tool for locating damage to insulation and other thermal leak points. Using these tools can identify problems with a building that are virtually invisible to the naked eye during a level 1 audit.

Finally, the “level 3” audit, or computer simulation, is the most extensive form of auditing. It involves collecting technical specifications of the building, like the R-values (insulation rating) of walls and ceilings, and entering them into modeling software to simulate where heat loss and other energy waste is occurring.

Our primary research presented us with these three options. In order to gather more information on an auditing process that we could perform during our 7-week on-site period, we first took inventory of the equipment we could use during our audit. Then we interviewed auditors for their opinions on suitable software and any recommendations for using the equipment we had. Finally, we researched and evaluated energy-use simulation programs that were available to us to see if they could be suitable tools for auditing APW.

Resources available through WPI offered us access to helpful auditing tools. Through Prof. Ludwig of WPI, we were able to borrow a thermal-imaging camera. Through Prof. Looft and Prof. Savilonis, both of WPI, we borrowed remote temperature data loggers, small battery-powered sensors that can be set to periodically record ambient temperatures for a given length of time. We also borrowed Prof. Looft’s Kill-A-Watt meter, which allowed us to measure the power draw of anything with a plug, and a spot-temperature gun, which could give us the temperature of a surface accurately to within one degree. Finally we employed more generic tools, such as a digital thermometer, to help program the thermal camera to give accurate temperature readings. After collecting what we could we prepared to interview professional auditors.

We designed our auditor interview to inquire about aspects of auditing that we had researched but were ultimately unsure how to practically accomplish. Some auditing tools are very specialized and hard to come by; by first taking inventory of the equipment we were going to be able to have access to, such as a thermal imaging camera, we were able to run our tentative auditing plan by the professionals and get their feedback. Also concerning equipment, we asked if there was any equipment that we did not have that they would recommend we get, and why. This was meant to shed light on any weaknesses present in our tentative plan so that we could determine exactly what our auditing capabilities were.

Aside from equipment, we also asked about software. Internet searches for energy auditing software yield vastly diverse results; there are many options available and many of them are free. We were looking to include software in our audit with the hopes that it would make our analysis either more precise or be able to give us more data on certain aspects of the building. The vast range of options available made us eager to get input from professional auditors on the software that they use and what they use it for to see if it was appropriate for our uses at APW.

As a conclusion to the interview, we decided it would be helpful for us to see if we could get an idea of any particularly effective technology, building improvements, or conservation measures that they had recommended or seen implemented effectively. The purpose of this was to get a professional, real-world perspective on any energy conservation projects that they had worked on or heard about so that we might have a better idea of some potential money-saving measures for APW.

The first auditor that we contacted for an interview was Peter Ottowitz of HawkEye Home Inspection, who had unique suggestions for us that helped shape the practical side of our energy audit. Mr. Ottowitz was initially skeptical about the quality and thoroughness of our proposed auditing plan, though he was impressed with our ability to use the thermal-imaging camera to analyze the building envelope because that is a major component of the auditing work he does for HawkEye. He directed us towards a number of excellent online resources for the effective use of thermal-imaging cameras in an energy audit. His primary recommendation for us in terms of equipment was a "door blower," which is a large fan built into a door-sized panel and is used to test the whole building for air seepage which would indicate thermal loss. We were familiar with that particular piece of equipment from our research, but it is relatively rare and we were unable to acquire one for our project[2].

For software recommendations, Mr. Ottowitz suggested HomeGauge, which is a professional-level paid licensed software program that makes generating home inspection reports much easier than doing it manually. He also suggested Home Tune-Up, another building-inspection program with some energy-specific input parameters. He was unable to comment on the vast number of free tools available, however, because he had never used them or heard anything remarkable about them.

For technology recommendations, Mr. Ottowitz expressed that implementing technology or conservation efforts are not his specialty because auditing that he does is the first step in a green building project, and implementation is usually the last. He did remark that he had heard success stories about rainwater-acquisition systems, and he said that he did not have a lot of faith in solar technology becoming mainstream, calling it, "a lot of hype."

Matt Beaton was another auditor that we contacted. He is a WPI alumnus and owns his own company: Beaton Construction. Beaton Construction performs energy audits for various building types. Mr. Beaton was very interested in advising our project.

Mr. Beaton was familiar with a few different software programs for energy-use modeling. The simulation software that he uses is REM/Rate but he has to use it under a costly license. He recommended a solution very similar to REM/Rate called TREAT.

[2] Mr. Ottowitz expressed that he would be willing to lend us his company's door blower if not for the fact that they needed it themselves on a constant basis.

He also described his auditing method in detail. He first uses a thermal imager to take infrared pictures of the building, then performs a combustion zone test, and finally collects all the relevant data of the building to compile a report in his software and uses that to make practical recommendations.

The final part of the process for determining an appropriate method of auditing to use at APW was a software evaluation. We investigated three programs: REM/Rate, TREAT, and RETScreen. We found that none of the programs were capable of effectively enhancing any aspect of the energy auditing capability that we already had. For instance, REM/Rate and TREAT are primarily focused on home inspections, not commercial buildings. RETScreen had more advanced energy modeling capabilities for commercial applications, but was limited by its focus on Canada; it could only reference weather conditions for Canadian regions in its modeling process. Ultimately we omitted the use of energy-modeling software in our analysis and instead focused on the walk-through, HVAC temperature data, and infrared building inspection to compose our audit process.

To summarize, energy auditing is a common and effective tool for locating energy deficiencies in a given building. The auditing process we determined to be most appropriate for APW and our group was an "enhanced" level 1, which consisted of a level 1 audit with more intensive measures that we were able to perform with the equipment we borrowed. It is important to note, however, that building efficiency is only one aspect of energy use in an office space. The other aspects are the users of the building: People. In the next section, we introduce an idea analogous to the energy auditing process; the difference is that we observed and inspected how the staff uses energy rather than the building.

2.3 Behavioral Assessment

Energy efficiency encompasses more than purchasing a certain kind of item or installing new efficient technology. Technology still has a role to play; however, an equally important aspect is human behavior. This consideration is significant because buildings do not autonomously use energy; People use energy. Top-of-the-line, Energy Star-certified lighting fixtures may be very efficient, but they will not save energy if the people using them never turn them off at night when they go home. For this reason it is important to ensure that people are aware of the impact that they have on energy use completely independently of the efficiency of a given building's systems.

Behavior is a significant factor in energy use. An example of the impact that behavior-only changes can have on energy bills is Prestonwood Baptist Church in Plano, TX. They worked with a nationally-acclaimed company named Energy Education to run an energy awareness and conservation program for their congregation and staff members. Their results are certainly impressive: Prestonwood Baptist Church saved 33% on its utility costs in its first year of the program, amounting to $892,000 in savings (www.energyeducation.com, 2009). 33% of Prestonwood Baptist Church's energy use was solely a result of "bad habits" in energy use; this study shows that in many cases, behavior is not second to technology in potential for energy savings.

Unlike the energy audit discussed previously, the process for a behavioral assessment is not standardized. The idea for this process was birthed from our experience with the APW building. We saw some office habits that stood out to us as being in need of optimization. For this reason we developed a means for a closer, more intensive evaluation of energy use habits at APW.

The basis for assessment we used was common, freely available advice for reducing energy use in an office setting. Common "energy-saving tips" include turning off lights when leaving, checking computer settings, turning off printers and other office appliances while not in use, setting up computer power management features, keeping thermostats set to an appropriate level, and keeping space heater usage to a minimum.

These measures are beneficial to any office, but we were concerned that simply telling people to do these things or even putting up posters would not have as much impact as we thought necessary to make a significant impact on energy use. The purpose of the behavioral assessment was to determine how energy was used so that we could state specific cost-benefit statistics and frame certain behaviors, like using a space heater liberally, within the actual costs involved. We determined that being able to put energy use into a simple and relevant financial context would also help us recommend policy changes for APW by supporting our recommendations with universally-understood statistics.

In summary, energy-conscious behavior is important to our goal of reducing energy costs at APW. We planned to assess the current state of energy use habits by the staff so that we would be able to make recommendations for behavioral changes that would have a significant impact. Next we discuss energy efficient technology available on the market today.

2.4 Green Technology

Our energy audit determined the effectiveness and efficiency of the building's systems. After this was done, poor or under-performing systems were recommended for replacement. What determines the feasibility of replacing these systems is the cost and suitability of replacement technology on the market. Thus, determining what is available on the market, what is suitable for APW, and what is the most cost-effective is of importance to our project. Here we discuss some available technologies, along with their benefits and capabilities, as an introduction to what some possible physical building improvements could do to reduce the building's energy use.

2.4.1 Building Envelope

Increasing the efficiency of a building's thermal envelope can be a very cost-effective way to conserve energy. Energy loss is mostly caused by the heat loss from the building, so this process primarily consists of insulating walls and floors. Some common causes of thermal leakages are:

- Plumbing penetrations through insulated floors and ceilings
- Chimney penetrations through insulated ceilings and exterior walls
- Fireplace dampers
- Attic access hatches
- Recessed lights and fans in insulated ceilings
- Wiring penetrations through insulated floors, ceilings, and walls
- Missing plaster
- Electrical outlets and switches, especially on exterior walls
- Window, door, and baseboard moldings

(www.aceee.org)

A common way to make a building energy-efficient is to insulate the attic and the basement using a fiberglass or cellulose insulation. The simplest way to insulate a basement is by installing rigid foam.

Windows and doors are another important part of building envelope. Every window in the building should be air sealed. Windows should also have an efficient frame material. Wood is the most common material in use for window frames but “Vinyl (PVC) windows, or vinyl frames insulated with fiberglass, are the most efficient and tend to insulate better than wood” (www.aceee.org). Coating the window with a transparent layer of silver or tin oxide can reduce solar heat gain (www.aceee.org). Double glazing the window will provide more insulation that a single glaze. Also, by using a lower conductivity gas such as Argon for the air in a sealed glass window, heat loss can be reduced significantly (www.aceee.org). Doors that serve as entrances or exits to the building and are heavily in use should be weather stripped.

The maintenance of a building envelope is relatively simple. It typically consists of making sure that doors and windows to the exterior of the building are weather-stripped and sealed properly so that there is no air leakage, and checking insulation for water leaks or any other irregularities. The presence of energy efficient systems in a building will be insignificant if the building envelope is compromised; inspecting these aspects of the building envelope and determining their condition is a necessary prerequisite to any renovations or other costly improvements that may be done to a building.

2.4.2 Lighting

Lighting is one of the major components of electricity use in any building. According to the U.S. Dept. of Energy, energy consumption of lighting accounts for 24% of all the electricity generated in the country (www.1.eere.energy.gov). There are many different lighting technologies available in today’s market. Table 1 summarizes lighting type, efficacy, lifetime, color rendition index, color temperature, and if it should be used indoors or outdoors.

Lighting Comparison Chart

Lighting Type	Efficacy (lumens/watt)	Lifetime (hours)	Color Rendition Index (CRI)	Color Temperature (K)	Indoors/Outdoors
Incandescent					
Standard "A" bulb	10–17	750–2500	98–100 (excellent)	2700–2800 (warm)	Indoors/outdoors
Tungsten halogen	12–22	2000–4000	98–100 (excellent)	2900–3200 (warm to neutral)	Indoors/outdoors
Reflector	12–19	2000–3000	98–100 (excellent)	2800 (warm)	Indoors/outdoors
Fluorescent					
Straight tube	30–110	7000–24,000	50–90 (fair to good)	2700–6500 (warm to cold)	Indoors/outdoors
Compact fluorescent lamp (CFL)	50–70	10,000	65–88 (good)	2700–6500 (warm to cold)	Indoors/outdoors
Circline	40–50	12,000			Indoors
High-Intensity Discharge					
Mercury vapor	25–60	16,000–24,000	50 (poor to fair)	3200–7000 (warm to cold)	Outdoors
Metal halide	70–115	5000–20,000	70 (fair)	3700 (cold)	Indoors/outdoors
High-pressure sodium	50–140	16,000–24,000	25 (poor)	2100 (warm)	Outdoors
Low-Pressure Sodium	60–150	12,000–18,000	-44 (very poor)		Outdoors

Table 1: Efficacy and Efficiency of Various Lighting Types
(http://www.energysavers.gov/your_home/lighting_daylighting/index.cfm/mytopic=12030)

Fluorescent lighting bulbs have one of the highest efficiencies available and they are able to generate acceptable amounts of light per watt of electricity used. Fluorescent bulbs also have a long lifespan, and for standard tubes are inexpensive at roughly $3-$5 per bulb. This means fluorescents can be very cost-effective in the long run, especially compared to incandescent.

The newest technology currently on the market is LED lighting, which claims to offset high costs for bulbs with 60% less energy consumption than comparable fluorescents. LEDs, or Light Emitting Diodes, are very compact sources of light that exist as semiconductors on a silicon board, just like modern integrated circuit electronics. Originally introduced in 1962, the capability of LEDs has gone from only producing low-intensity red light to being able to produce bright light across infrared, visible, and ultraviolet ranges. Currently LEDs are not used as area lights because of their small size, but their low heat dissipation and energy efficiency have made them obvious candidates for modern, high-efficiency lighting solutions in residential and commercial spaces.

Just as fluorescent technology was marketed against incandescent for its efficiency, now LED lighting technology is being marketed against fluorescent for efficiency, as well as environmental (harmful substances, like mercury, are not found in LEDs but make fluorescents costly and sometimes dangerous to dispose of) and productivity or comfort (fluorescent lights can visibly flicker, which can cause headaches) concerns. There are a few companies actively marketing the superiority of LED-based lighting solutions that can replace standard T8, T10, and T12 fluorescent bulbs, usually with some change in wiring configuration but in some cases they can be complete drop-in replacements, requiring no modification to the fixtures.

The AIDS Project Worcester building, like most office spaces, already utilizes fluorescent lighting fixtures for almost all of its installed area lighting. Not all fluorescent lighting, however, is created equal. Upon inspection, it is clear that APW's lighting fixtures were probably installed in the early to mid 1980s (which makes sense because that is when the building was last renovated). This is important because since then two developments in fluorescent technology have made the lights even more efficient by a significant factor.

One of the developments is the switch from T12 bulbs to T8. These two designations refer to the diameter of the tube; T12 is twelve eighths of an inch, or 1.5 inches. T8 then is eight eighths, or 1 inch in diameter. T8 bulbs are more efficient than their older T12 counterparts by about 10-15% and cost the same. In fact, since T8 bulbs have become mainstream they have almost completely phased out the use of T12s. T8 bulbs fit in the same fixtures as T12s and can usually use the same ballasts.

The second and more important development is the introduction of electronic ballasts to replace magnetic ones. Ballasts are required by all fluorescent lighting because the bulbs have certain voltage and current demands in order to function which are different than a direct line (120V) can supply. For that reason, they condition the power so that the lights can operate correctly. Before the mid 80s, magnetic ballasts were the only way to do this. The problem with magnetic ballasts, however, is that they require a 10-13W overhead to operate, and also use energy even if a bulb is burned out or not there.

Electronic ballasts solve this problem by replacing the magnetic system with integrated circuits, resulting in much higher efficiency and virtually no power draw when not driving bulbs. Magnetic ballasts draw 10-13W, while electronic ones draw as little as 3W to operate.

NationalGrid, APW's electricity utility provider, provided them with a free audit of their lighting system and an "energy savings plan" that involves replacing the 34W T12 bulbs and magnetic ballasts that are currently there with 28W T8 bulbs and electronic ballasts. The cost of doing this, according to their report, is $6062.84, of which NationalGrid will pay 70%, leaving the cost to APW at $1546.02. In order to determine if this was the most cost-effective and worthwhile solution, we looked into any competing technologies; namely, LED.

On paper, LEDs sound great. They can reportedly be up to 50% more efficient than the fluorescent bulbs they replace, and are meant to last 5-10 times as long. While the price per bulb is much higher (70-150$ per bulb for LED, compared to 2-4$ per fluorescent bulb), with their long lifespan and high efficiency, they could still easily pay themselves off and be the lower-cost solution over the long term.

While the previous statistics are impressive, they were also supplied by the retailers of the bulbs. Attempting to get a third-party review of these bulbs is not easy because they are still relatively obscure products, especially the fluorescent tube replacement models. Mass-marketing a $150 light bulb is not an easy task, and so these bulbs currently have a very small foothold in the market.

Fortunately, the Dept. of Energy, as part of their market-research program known as "CALiPER," performed an extensive review of a number of LED light fixtures, including four different 4' fluorescent replacement bulbs (exactly the kind that APW would require). In short, their findings show that these LED fluorescent-replacement tube lights only produce half of the amount of light that T8 bulbs produce per watt. They also show that the retailers and manufacturers of these LED "solutions" in some cases egregiously overstate the capabilities of the bulbs. Figure 1and Figure 2 show the comparison between lighting types.

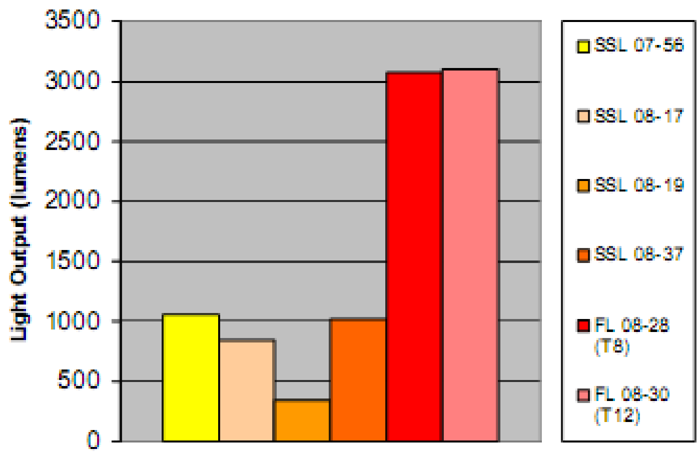

Figure 1: Output of 4' LED Bulbs (SSL) and Standard Fluorescent (FL)

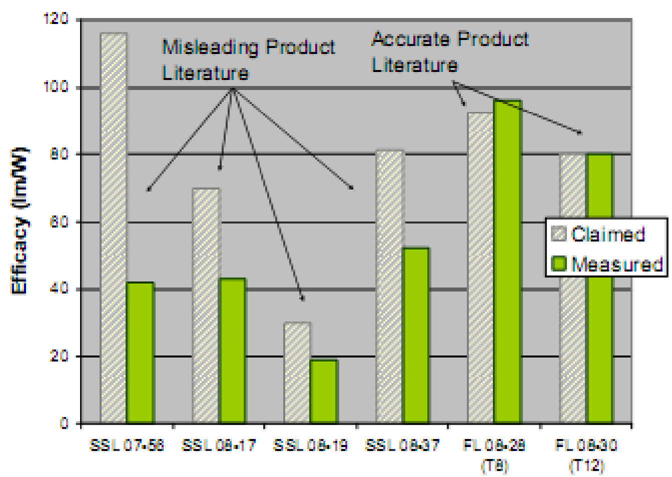

Figure 2: Measured efficacy (Light output per watt) versus manufacturer claims in 4' LED (SSL) and fluorescent bulbs (FL)

Figure 1 is the more important of the two charts, showing that the light output of any of the LED solutions is not even close to that of a comparable fluorescent bulb. Even the best performing LED only put out 33% of the light of fluorescent bulbs. Part of this, according to the report, is because of the inherent difference between the lighting solutions; LEDs are purely directional, while fluorescent tubes light all directions around the tube equally. Since LED tubes orient the LEDs facing downwards, existing fluorescent-designed fixtures, which are meant to reflect back light that the fluorescent bulbs display towards the ceiling, are poor applications for LED solutions. This fact is reinforced by the DOE report's other lighting benchmarks, which found that fixtures designed specifically for the unique characteristics of LED lighting perform much better to the point where they are on par with fluorescent or incandescent in terms of lighting performance.

Figure 2 shows the potential danger of accepting a manufacturer's or retailer's claims about untested technology. While one manufacturer significantly overstated the lighting performance of their LED solution, three out of the four LED bulbs underperformed the manufacturer claims. Considering that one major aspect of the supposed cost-benefit of LED is the bulb's longevity (usually claimed at between 50,000-70,000 hours, or 5-10 years depending on use). The bulbs have not been on the market long enough for anyone to test those claims independently, which puts anyone interested in buying them at major risk of not making their investment back. Given the $70-$150 cost per bulb of the LED replacements, the life of the bulb is crucial to the eventual payback in energy savings. Data that casts doubt on manufacturer's claims lead us to be skeptical about the supposed positive cost-benefit of LED fluorescent replacements.

In conclusion, T8 fluorescent bulbs are the only feasible replacement for the T12s that APW currently uses just based on the light output limitations of the LED replacements on the market. Replacing a T12 fluorescent with an LED that outputs 66% less light and costs 20-50 times as much is not an intelligent investment no matter the energy savings. While we believe that LED will inevitably become a dominant lighting solution in the coming years, at this point the technology is insufficient to perform as a direct replacement for fluorescent tubes.

Extensive analysis has shown the dominant lighting technology currently available to be fluorescent. Even within that technology, however, advances have improved the efficiency of the bulbs and ballasts significantly; fluorescent bulbs and fixtures that are over 10 years old may be easy candidates for replacement.

2.4.3 Thermostats

The second major source of energy use in an office building is heating, ventilation, and air-conditioning (HVAC) systems. Estimates place the average proportion of energy use by HVAC systems at 50% of all building energy consumption (Pérez-Lombard, et. al. 2008). APW's HVAC system has not been significantly altered since it was installed over 20 years ago. They currently have 6 HVAC units.

Advances in HVAC technology have made the units themselves more efficient but modern technology has also been applied to their common controllers: thermostats. At APW, their 6 HVAC systems are controlled by three different kinds of thermostats. Three units are controlled by programmable thermostats that date back to the mid 1980s. Two of them are controlled by newer programmable thermostats, and one of them is controlled by a standard, non-programmable one. This section discusses various kinds of thermostats on the market for office buildings and the benefit they offer end-users.

The most important new feature to be added to thermostats since programmable timers were made available in the mid 70's is networking. Network thermostats can communicate either with a computer or each other via wired or wireless transmissions. Another feature common among new thermostats is a pre-set "eco-mode" designed to minimize energy use when heating or cooling a building. This usually entails more stringent temperature thresholds; where a person programming a thermostat may program it to maintain a 70^o temperature during winter months, an eco-mode would drop that to 68^o or even lower to reduce energy consumption.

There are two basic functionalities that networking can add to thermostats: one is the ability to remotely control one or more thermostat in a building over the internet, in order to alter settings without having to be at the location. This feature is typically marketed more towards residential consumers, who could use the ability to turn off their heat at home while at work or on vacation, or further alter the thermostat schedule to match when they will be present in or absent from their homes.

The second is the ability for thermostats to communicate with each other, which can allow a "smart" system to monitor and manage how much energy the systems are using at any one time. A number of WPI buildings recently utilized a state-of-the-art thermostat control system which manages the operation of the HVAC units to avoid peak rates from their utility provider. It does this by essentially running the units in sequence instead of simultaneously, which lengthens the amount of time required to fully heat the building but reduces costs by keeping consumption rates below the "peak consumption" threshold that incurs higher rates.

We discuss two thermostat systems we found to be unique below. The first is a residentially-oriented, fully networked, and centrally-controlled system made by a relatively new company called Ecobee. The second is a commercial- and industrial-grade system that has more advanced networking capabilities, but comes at a higher cost and is generally more complicated to install and use.

The company Net/X offers a line of network thermostats that are highly advanced and controlled by a central module that interfaces with a computer system. The controller communicates with the remote thermostats via wire unless the system is upgraded to support wireless communication; this upgrade requires that a wireless add-on be purchased for every remote thermostat, as well as the controlling module. The controlling module itself is capable of communicating and managing up to 16 thermostats, and the wireless add-ons have a tested range of 1,000 feet. They communicate over a unique radio frequency so that they do not interfere with existing wireless networks. Schedules for each thermostat can be created on any computer, then downloaded to the controller module. The software does not offer built-in access over the internet. A system sized for APW would consist of 6 thermostats, 6 wireless add-ons for those, a central controller, and a wireless add-on for that and would cost about $3300 for the equipment alone.

Ecobee recently released a line of network thermostats that focus on ease-of-use and flexibility. Their thermostats communicate via existing wireless networks instead of using their own dedicated frequency, and the system has no central control unit; the thermostats each store their own schedules as programmed via the device itself or any computer on the network that has the software installed. The software has built-in remote access functionality so that settings can be changed over the internet from a computer or iPhone (via a dedicated app). Each thermostat has a large color touch-screen for display and input. The software can support multiple thermostats at a time, and is designed to be simple and user-friendly. A system sized for APW would consist of 6 thermostats, and would cost about $2000 not including installation.

In summary, thermostats (even programmable models) have come a long way since 1985. A preliminary look at APW's thermostats, three of which date back to the mid-1980s, prompted a more in-depth analysis of the HVAC controllers and the cost-effectiveness of replacing outdated or malfunctioning equipment.

2.4.4 Capital Improvements

The conservation technologies mentioned above are a key element of green implementation for any building trying to become more sustainable. These technologies are usually easy to implement, relatively inexpensive, and generally focus on improving existing building features rather than adding new ones. However, there is another key element that is important to consider for a building that is working towards maximum energy efficiency, and that is the larger, more ambitious green technologies. These types of green technologies, such as green roofing and photovoltaic solar cells, are different than the conservation technologies in that they have a much larger upfront cost and typically pay themselves back over a longer period of time. However, in the long run these technologies can have a much greater impact on the sustainability of a building.

Green Roofing is a type of green technology that, while it has a large upfront cost, can offer many short- and long-term benefits to the building. The primary benefit of a green roof is the excellent insulation that it provides to the building. A green roof is able to reduce the amount of heat gained by the building from the sun in the summer and reduce the amount of heat loss from the building in the winter, which can significantly impact the energy costs for the building year-round.

Another advantage of green roofing is that it increases the life expectancy of the roof. This is possible because the green roof is able to protect the roof from extreme temperature swings, ultraviolet radiation, and physical punctures that would require maintenance and eventually a costly replacement.

Storm water runoff management is another benefit of green roofing. Instead of storm water runoff peaking during the middle of a storm as it does on conventional roofs, a green roof controls runoff by retaining rainwater and releasing it after the peak if the storm has passed. This is especially relevant to APW's location in the Blackstone Canal district, which is plagued by the effects of peak storm water flow erosion on the condition of the area watershed. This problem is currently proving to be a major issue for the city, and curtailing a portion of the cause of this problem can greatly benefit the community local to APW and the canal district.

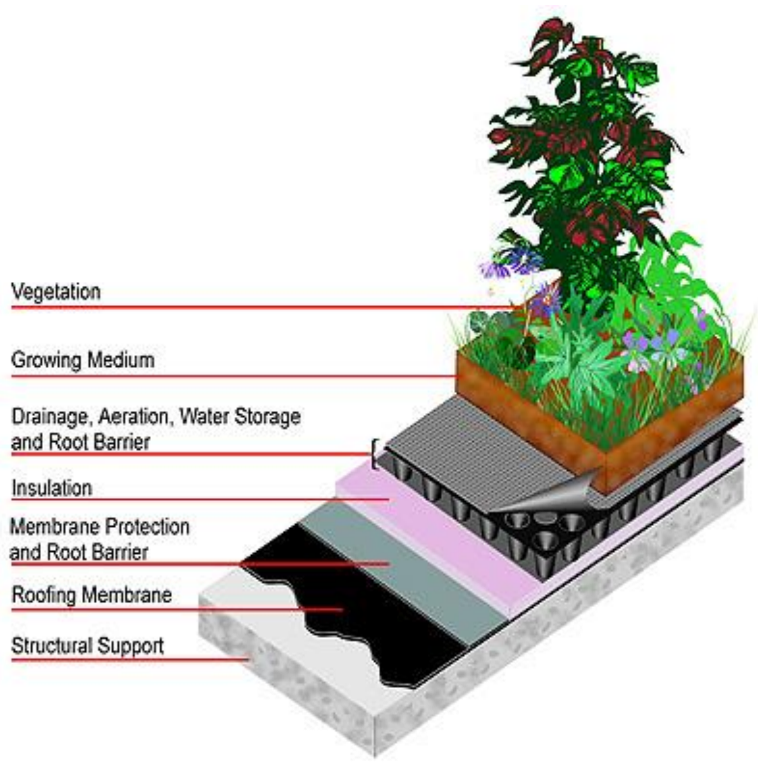

Figure 3: Components of a Green Roof (www.villanova.edu, 2009)

A green roof is comprised of three main layers; waterproofing, soil and plants. For the waterproofing layer, there are many options available to choose from. Some of these materials include a rubber membrane (EPDM), hypolan (CSPE), thermoplastic polyolifins (TPOs), and PVC (http://www.edcmag.com). Out of these available choices, PVC has many benefits that make it a good choice as the waterproofing material. For example, PVC is heat-seamed, so there is a reduced chance of leaks, it offers root protection, it's efficient and cost-effective, and it has more functions than the other waterproofing materials so there isn't a need for additional materials (http://www.edcmag.com).

The next component of the green roof, soil, is a key aspect because it is the growing medium of the plants. Any organic soil performs well in this application; topsoil would be a good choice for the growing medium because it is mostly organic material and would be the outermost layer of the roof. The final component of the roof, the vegetation, is the most important layer of the green roof. There are many options available in choosing plants for a green roof, but there are a few things to consider when one is choosing the plants. The conditions on the roof are different than the conditions plants face on the ground; the plants must be hardy and able to survive long hours of direct sunlight and high wind speeds. The climate will also influence the choice of vegetation, and even the type of green roof is a factor in the decision.

There are two main types of green roofs: intensive and extensive. Intensive green roofs have larger plants such as shrubs and trees and need irrigation systems and regular maintenance. They also require at least foot of soil and put a heavy load (80-150 lbs. per sq. ft.) on the roof, around (http://www.edcmag.com). Extensive green roofs on the other hand require around 1-5 inches of soil and have a load of 15-50 lb/ft^2 (http://www.edcmag.com). The other difference between the two types of green roofs is that extensive green roofs can be used as a public garden, while intensive green roofs are not intended to be used as such.

Another green technology is a photovoltaic (PV) system, which is a group of solar cells (or panels) that convert solar energy to electricity. This is possible due to the photovoltaic effect. The photovoltaic effect is when sunlight (photons) collides with the electrons in the solar cells. The electrons of the solar cells gain energy from the collision with the photons and are able to move more freely, and this creates a direct current (DC). Buildings run off of alternating current (AC) electricity so power inverters are used to convert the power type.

Figure 4: Solar Panels on a House

There are two main types of building materials for solar panels: crystalline silicon and thin-film. Crystalline silicon has been the established technology for solar panels. There are two main types of crystalline silicon, single and polysilicon. Single silicon has a low cost at $4/Watt, and a conversion efficiency of 10-15% (Solar Electricity). Polysilicon has a faster growth and cheaper materials, but due to the structure of polysilicon, the module cost is roughly the same (Handbook of PV). Also, the efficiency of polysilicon compared to single silicon is lower by a few percent (Handbook of PV). The three main types of thin-film building materials are amorphous silicon, copper indium diselenide ($CuInSe_2$), and cadmium telluride (CaTe). Thin film materials have conversion efficiencies similar to the crystalline silicon. The costs of the materials for thin-film are higher than crystalline silicon, because silicon is widely available and only needs to be purified and the thin-film materials are rarer than silicon. The main advantage that thin-film materials have is that they lower the module cost of the solar cells (Solar Electricity). This is possible because thin-film modules can be manufactured in larger volumes and lower costs than the crystalline silicon modules (Solar Electricity).

This area of green technology has been advancing rapidly over the last decade; in fact it is currently the worlds-fastest growing energy technology (http://www.socialfunds.com). Like green roofing, PVs have a large upfront cost, but also provide many benefits. One benefit is that solar energy is readily available in any location in the world. Even though the efficiency is not that high (typically around 20-30%) the sun produces so much energy that PVs remain a viable option for green energy. The obvious benefit of such an array is essentially free energy; aside from cost of installation, PVs have absolutely minimal maintenance and operation costs. Also, if the PV cells are generating more electricity than the building uses, utility companies in Massachusetts are required to credit that “bonus” electricity back to the building. A very sunny day when the building is not being used could pay for a cloudy day of heavy electricity use through the credit system, so it eradicates the need for expensive battery systems to gain from the arrays when the building is not in use.

As previously stated, a photovoltaic system is a capital improvement, and requires a large upfront cost. This large cost is daunting to many consumers, both commercial and residential. However, there are options available to alleviate the cost of a photovoltaic system. Two popular financial options that are available are leasing and Power Purchaser Agreements (PPAs).

According to the Environmental Protection Agency, a PPA is “financial arrangement in which a third-party developer owns, operates, and maintains the PV system, and a host customer agrees to site the system … and purchases the system’s electric output from the solar services provider for a predetermined period” (EPA, 2009). Essentially, an investor agrees to pay for the solar installation on a given building and then sells the energy it produces to the building tenants at a constant, previously-arranged rate.

The main benefit that makes it an attractive financial option in some situations is the zero up-front cost to the customer. Operations and maintenance are provided by the solar service provider throughout the period of the agreement. The solar service providers receive financial benefits from the PPA as well. These benefits include tax credits and income from the electric output purchased by the customer (EPA, 2009). PPA agreements are more complicated than buying a PV system because in many cases the building owner does not own the system.

2.5 Funding the Projects

Every example of technology mentioned previously has one thing in common: they all cost money. The high cost of these improvements is one of the primary deterrents from the rapid spread of energy-conscious, efficient technology. Fortunately there are ways to lower the total cost of many of these upgrades or installations by applying for funding from various other organizations, the largest of which is the U.S. government. As an integral part of any cost-benefit analysis, some of these funding sources are discussed in detail below.

The first level of funding we considered is federal. Many federal government funding sources are offered through tax credits or tax incentives as opposed to rebates or other cash payouts. Since AIDS Project Worcester is a non-profit organization and does not pay taxes, their organization cannot directly benefit from these kinds of rebates. However, APW does not own their building; they are a long-term leasee to a private building owner. This means that while a non-profit group like APW may be ineligible to benefit from tax-incentive based options, the owner of the facility is not. Any improvements done to their building are potentially eligible on two levels; one as a non-profit, the other as a privately-owned building. This created a unique dynamic: we investigated funding options that apply to either APW or the building owner to determine which ones are more substantial and subsequently who should be representing the building when applying for upgrades and associated funding. Securing enough funding to improve their building will be the ultimate target for APW before they begin to implement any energy-saving technology or building upgrades.

At the national level, the United States Department of Treasury is offering money towards the investment in the power generating technologies (U.S. Department of Treasury, 2009). These technologies include such things as solar power, wind power and fuel cells. In order to receive such a grant, applicants must fill out an application and submit it in order to be considered. For nonprofit organizations they offer a loan anywhere from $5,000-$100,000 for solar water, heat, and electric systems (U.S. Department of Treasury, 2009). The projects are judged and determined viable, then given loan terms.

State level funding can be awarded through the Massachusetts Technology Collaborative Renewable Energy Trust (Renewable Energy Trust, 2009). The trust provides financial assistance to individuals and businesses for the development of solar and wind turbines at their facilities. They have programs for individuals, business and nonprofits, communities and so on. This trust is able to provide essential funds for implementing renewable-energy installations, like small wind turbines and solar panels. There are different types of criteria which the Massachusetts Technology Collaborative (MTC) considers:

> **Potential public benefits:** MTC will evaluate an application based on the degree to which it furthers the public purposes specified in the enabling Legislation. To this end, where appropriate, preference will be given to projects located in Massachusetts and renewable energy technologies that are manufactured in the state.
>
> **Net cost per kWh:** MTC may consider the projected net cost per kilowatt-hour of the renewable energy system. The net cost will be estimated based on the annualized total system costs, accounting for potential energy savings and other benefits.
>
> **Commercial potential:** MTC may judge an application based on the degree to which it is likely to advance the commercial prospects of the underlying renewable energy technology.
>
> **Geographic location:** As electricity consumers throughout the state contribute to the Trust, MTC will strive to support applications in all regions of Massachusetts.

Leverage of the Trust's resources: MTC may consider the strength of the financial obligations of other parties involved in a particular application. Financial leverage is important to demonstrate commitment, to validate commercial potential, and to maximize the impact of the Trust.

Contribution to public debate: MTC may consider the degree to which a particular application furthers increased awareness of renewable energy and its relative costs and benefits because such increased awareness is essential to the success of our renewable energy programs. (Renewable Energy Trust, 2009)

In summary, funding is a key aspect for APW to realistically implement renewable-energy technology. Various funding opportunities can give APW a chance to get the required capital for these projects.

2.6 Summary

The information collected in this chapter provided a better understanding of the problems that we dealt with in this project. The information gathered on how to approach "greening" a building through LEED and Energy Star standards was helpful in familiarizing ourselves with current methods for energy efficiency and the concept of a "green" building. Researching energy auditing helped us determine the appropriate methods for our analysis of APW's building. Discussing how behavior plays a role in energy use led us to address occupant use of technology. Our research on available green technologies was crucial in making recommendations for APW to invest in energy-saving building upgrades. Finally, examining funding sources to implement those technologies determined the cost-benefit and time frame for implementation of our recommendations. In Chapter 3, we discuss how we carried out the objectives we synthesized from our research.

Chapter 3: Methodology

This chapter describes our concrete process for completing our objectives. Our objectives were to perform energy and behavioral audits of the building and then synthesize behavioral and technological recommendations, including funding analyses, based on our findings. With these objectives in mind we further refined them by determining specific tasks necessary for their completion. This section outlines the objectives and corresponding tasks we determined to be paramount to our ultimate goal of reducing the energy costs of APW.

3.1 Performing an Energy Audit

Our first objective for helping APW lower energy costs was to perform an energy audit on their building. In our background we discussed our auditing capabilities and reviewed the three main levels of audits. Then we synthesized a hybrid auditing process by determining the equipment we could use, interviewing auditors, and evaluating software. In this section, we discuss in detail the three part process we developed from our background research.

The first component to our process utilized a walk-through checklist from the WSU Energy Audit Workbook to guide a visual inspection of the building. Through this we inspected the following building characteristics:

1. Building envelope
2. Building occupancy
3. HVAC - Controls
4. Power consumption

The checklist guided us through a qualitative analysis of the maintenance and operating condition of the building, and contains a list of “suggested O&Ms” (operations and maintenances) for each subcategory. The complete list can be found in Appendix A.

We completed the entire list except for two sections: HVAC and lighting. We omitted all but the controls section of the HVAC because we lacked sufficient technical knowledge of HVAC operation to be able to determine their condition as required by the checklist. We were comfortable omitting the HVAC section because we used temperature data loggers to collect quantitative data on HVAC operations in a different section of our audit; this data offered a more comprehensive analysis of the HVAC system than a simple visual inspection could have. We omitted the lighting section of the checklist because during the course of our on-site work, APW had all of their lighting replaced as part of an energy savings program offered by their electric utility provider. All the lights are now brand new and efficient, so the lighting section of the checklist was not included in the inspection.

After we walked through the building inspecting its systems, we compiled a list of suggested operations and maintenances (O&Ms) and energy conservation measures (ECMs). These are tips and techniques provided by the workbook to be suggested solutions to problems identified in the inspection process. In order to make referencing these suggestions easier for APW, we pulled them out of the checklist, where they are divided by category and mixed in with the checklist options, and created a centralized list of O&Ms and ECMs for APW (Appendix A). We used this list as a basis for determining appropriate technology upgrades in the next section, and passed it on to APW for reference as they look for further opportunities for reducing their energy costs.

The second stage of our audit process evaluated the HVAC units and how well they are being controlled and coordinated by the thermostats. APW has six heating zones, each with its own HVAC unit and thermostat. We evaluated these systems by placing temperature-recording sensors inside the vents of the ducts in each zone to take temperature readings once per minute for 8 consecutive days. We left them there to collect data while the staff used the building as they normally would. At the end of the 8-day testing period, we removed the sensors and compiled all 75,000 temperature readings into a spreadsheet. We then developed an algorithm to estimate the fuel consumption of the units based on the temperature data we collected, and converted those consumption estimates into cost estimates. The calculations that formed our algorithm can be found in Appendix B.

Figure 5 shows an example of the data we collected from the temperature loggers for one of the six zones. The sharp rises and falls in temperature indicate when the units turn on and off. The rapid rise-fall appearance of the graph indicates cycling of the units to maintain a specific temperature as controlled by the thermostat. We developed an algorithm to process all the temperature recordings we collected so that we could estimate fuel consumption and convert those estimates into a cost analysis of the system.

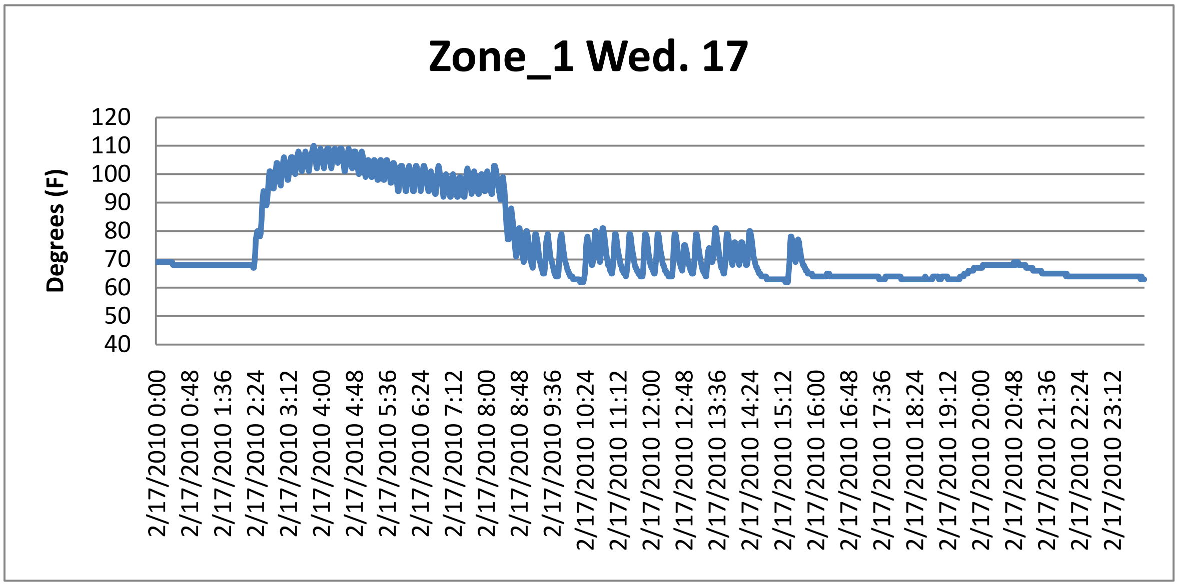

Figure 5: 24-hour Temperature Reading in Zone 1, 2/17/2010

The third and final part of our energy audit was inspecting the building envelope with the thermal camera. The thermal camera allowed us to see thermal patterns in the building that indicated damaged or insufficient insulation, air or water leaks, and other thermal inconsistencies.

We focused on a few key areas in the building when scanning for thermal irregularities. The first places we looked were areas that showed clear signs of water damage from the interior. The staff directed us to certain areas where water would consistently leak through their roof when it rained; these spots were also identifiable by discolored drop-ceiling panels. Next we inspected two areas that seemed likely candidates for thermal leaks because of a perceptible drop in air temperature. One was a rarely-used emergency escape staircase that led to the exterior of the building. The other was a closet on the interior of the building. Exterior doors and windows were also high priorities in our thermal scans. Finally, we scanned the roof for thermal irregularities once when snow was covering most of the surface and again when the snow had melted.

These three components allowed us to evaluate key energy-using systems in the building. This process was an integral part of forming recommendations for APW to lower their energy costs. The other crucial aspect to the recommendation development process, the behavioral audit, is discussed below.

3.2 Behavioral Audit

While we collected technical data about the building systems in our energy audit, we also collected information on energy use related to how the staff used their office equipment. In order minimize disruption of the normal working day, this process consisted of making observations of the office space after-hours when most of the staff were not present. We examined computer settings, programmable thermostat settings, lighting use habits, and anything else relating to energy consumption in direct control of the staff. The goal was to note and measure the energy use of anything used, influenced, or effected by the tenants of the building.

During our inspection, we looked to see exactly what was left running in each office and checked computer settings under the "Power Management" section of Windows XP (the OS of choice for APW). Also, we plugged the various computer models into our Kill-A-Watt power meter, which gave us a reading of the power draw (in watts) of the computers and monitors in full-power, standby, and shut-down states. In this office-by-office check, we took inventory of all the space heaters in the building and tested their power draw. Any other characteristics which we found to be significant we documented as well, such as the presence of incandescent desk lamps.

By collecting data on the power consumption and operating hours of the office equipment, we calculated cost estimates for certain behaviors. By translating our findings into a monetary value, we were able to measure and compare all aspects of energy use using the same standard. This data formed the basis for our behavioral evaluation by giving us insight into office trends and estimates for the costs involved.

3.3 Developing Short-Term Recommendations

The data we collected from our behavioral audit was used to compose our short-term recommendations, which are meant to cost little to nothing. For that reason, they can be carried out over a short period compared to more expensive technological upgrades or building improvements. We developed these recommendations by following two steps with the behavioral data we collected: identifying areas for improvement, and determining ways to improve those areas.

We identified areas for improvement by analyzing our power consumption estimates for the office equipment. By examining both the total running time for a device and its power consumption, we determined what percentage of APW's electricity bill was going to power each group of devices. Then we compared the total running time for the devices to the working hours of the staff, and calculated the cost of running each device for an 8-hour work day. Finally, we compared the costs to see if the devices were costing more as part of their actual operating schedule than they would for an 8-hour work day.

The next step was developing best practices so that the staff could work normally but still save energy. The balance between these two things is important. For example, we could have recommended that the workers turn off their heat during the winter entirely to save money on energy costs. While turning the heat off would certainly reduce their energy costs, the staff would not be pleased with their working environment, which would result in a distinct loss of productivity. "Best practices" aim to present feasible, relatively simple tips for reducing energy use without any loss of comfort or productivity. The application of these "best practices" to the staff became our short-term recommendations.

3.4 Developing Medium- and Long-Term Recommendations

While our short-term recommendations cost very little money, the technological upgrades and building improvements that we saw the need for at APW could not fall into that category. For this reason, we developed medium- and long-term recommendation categories to form a relative timeline for the implementation of energy-saving measures. The development of these recommendations stemmed from our energy audit data and our research on available technology. The energy audit examined the building and where it needed improvement, and through our technology research we determined possible avenues to pursue when recommending building upgrades.

In order to narrow down all these possible technological upgrades, we examined each technology with four criteria: the documented effectiveness, the cost of implementation, the feasibility of implementation, and the estimated payback period. We chose these criteria based on the specific needs of APW and what was appropriate for them and their building. They are a non-profit organization and so rely on donations and government grants. The limited funding availability of such an organization required that any potential recommendations be examined closely using this criteria so that our recommendations would be designed to have the maximum impact on their energy costs.

Effectiveness of technology evaluates the technologies' energy efficiencies. This allowed us to compare the rated efficiencies of technology on the market with the rated efficiencies of the existing systems at APW. The cost of implementation determined the recommended time frame for recommendation; somewhat expensive upgrades were recommended for medium-term period and very expensive technologies were recommended for implementation over a longer time period. Another factor in the time frame division was the importance of the order in which they were performed. For instance, if we recommend solar panels for APW but we also recommend replacing the roof, roof replacement should come before solar panels because of the added costs of repairing a roof with an existing solar installation.

Feasibility in implementation checked the technology against APW's building. Some upgrades seemed very promising as we examined their cost-benefit and energy-saving features, but as we researched the requirements for installing or running these technologies, we found many to be incapable of helping APW at all because of the size, location, or type of their building. The payback period is the last criteria and compared the cost of the technology in question with how much money it was capable of saving over a given period. Using these criteria, we made recommendations for building upgrades that would allow for APW's bill to be consistently reduced from the short-term to the long-term.

The final component of making recommendations that would cost money was formulating a potential plan for funding the upgrades. In our background we discussed the funding sources that are available from the state and federal government. The final component to completing our recommendations selected potential sources that were relevant to the technology and to the organization. More importantly, the funding components of our recommendations also examined funding plans involving the building owner based on the type of upgrade and the eligibility differences between a non-profit organization and a private building owner.

In Chap.3, we discussed our methods for our energy and behavioral audits and our process for developing recommendations for APW. These methods formed the core of our work during the 7-week project term. They proved critical in identifying the energy needs of the building and the energy habits of the staff so that we could address problems directly and appropriately. In Chap. 4, we present our findings alongside our recommendations for APW to lower their energy bills.

Chapter 4: Findings and Recommendations

This section presents and discusses the results from the data collection performed in the methodology section. Our recommendations are split in three sections – short term, medium term, and long term. The findings related to those recommendations are present in each of those sections.

4.1 Short-Term

4.1.1 Behavioral Audit Findings

Our behavioral audit involved looking for behavior-related energy use. This category of finding includes the office practices of the staff - the use of space heaters, computer settings, and lightning use. For each of these we were able to perform a cost-benefit analysis.

We found from our behavioral audit that the staff of APW uses eight space heaters. We found that a space heater at the maximum setting (of two) consumes approximately 1400 W. Assuming that one staff member uses the space heater during half their working day (4 hrs.), it would cost APW about $0.88 per day. In a month this could amount to $26.36. Since the space heater is used for roughly four months out of the year (Nov.-Feb.), the cost of running just one space heater could cost APW approximately $105.46 annually. APW has 8 eight space heaters which are used by the employees during their working period in winter months. We approximated that APW spends at least $843.66 every year on the electricity required to power space heaters.

While conducting our behavioral audit we found that all the office lights were turned off. However, the hallway lights were still left on, totaling 24 28-watt light bulbs in all and 12 3-watt ballasts. The amount of energy consumed by these lights is 708 Watts. If the hallways lights are left on during non-working (roughly 14.5) hours, then the building consumes 10.26 kWh every day in unnecessary lighting. This amounts to approximately $1.61every day. We estimate that APW spends approximately $588.03 on unnecessary lighting annually.

We also observed that the staff leaves their computers “on” during non-working hours. This consumes a lot of power that APW can easily save. APW has a few different types of computers that each have slightly different power requirements; for accurate results, we measured the power usage of each type of computers when on (idling), on standby, and off.

These computers are left on during non-working hours (approximately14.5hrs), which means the building can save 37.76kWh per day by changing their computer policy to mandate shutting down computers at the end of the day. For remote-desktop users, using the wake-on-LAN feature that almost all of the APW computers have would allow them to remotely power on the computer or wake it from standby. This feature can be accessed using the same software that APW already uses for remote desktop: LogMeIn. The following tables and figure summarize the savings over a period of 1 year:

Number of Computers	Power Consumption	Working Hours	Non-Working Hours	$/kWh
31	2.604 kW	9.5 Hours	14.5 Hours	$0.15693

Table 2: Computer Power Requirements

Time Period	1 day	1 month	6 months	1 year
Savings	$5.93	$177.90	$1067.40	$2134.80

Table 3: Potential Savings for Computer Systems

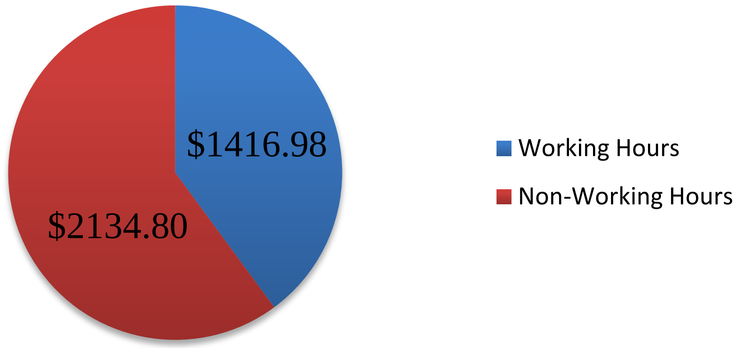

Figure 6: Annual Cost Breakdown of Computer Operation

We estimate that APW can save around $2,134.80 annually by shutting down their computers when not using them and using the wake-on-LAN features of their remote desktop software to cut computer operation time.

4.1.2 Recommendations: Behavior and Policy Change

We recommend that AIDS Project Worcester implement a policy for the staff members to limit the use of space heaters. We understand that the need for space heaters is a result of the inconsistencies in HVAC performance. As a temporary measure until those inconsistencies are resolved, we recommend that the staff bring a sweater to work instead of using the space heaters. While we address the HVAC problem later in this chapter, we agree that if APW wants to reduce their energy costs, one effective solution is to ask the staff to wear layers instead of using space heaters for the time being. If APW decides not to curtail space heater operation completely, we recommend the use of timers on space heaters. In our behavioral audit, we found one room that had its space heater left turned on for the night. Timers would remove the possibility of space heaters being left on at night or over a weekend.

One such timer called the Indoor Digital Light and Appliance Timer costs $13, which means eight of these cost $104. While that is fairly inexpensive, we are not sure of the payback period on such an investment because we could not accurately observe how many nights or weekends space heaters would be left on in the office.

We also recommend that APW implement the policy of making sure that the hallway lights are turned off after hours. To make sure that the lights are turned off when necessary, APW can also use motion sensors or timers on the hallway lights. The most cost-effective way to reduce lighting cost is to make sure that the staff member responsible for closing the building remembers to turn off the hallway lights.

For the computer settings, we recommend that APW change its computer policy from “always on” to “off when not using.” Currently, staff members are instructed to leave their computers on all the time for any maintenance that their IT technician does. We spoke with the IT technician, and he did not seem to have any problem with changing that policy. The savings such a policy change would create make it a very easy way to save $2000 per year. For remote desktop users, using the "Wake-on-LAN" feature of LogMeIn to remotely wake up or power on their work computers is an easy way to reduce the operating time of their machines.

4.2 Medium-Term

4.2.1 Building Envelope Findings

To determine the “unseen” energy losses in the buildings envelope, we used a thermal-imaging camera. The thermal camera allowed us to determine how effective the buildings envelope was, specifically looking at areas such as the roof, windows, and doors. A thermal imager works by translating invisible infrared light, which radiates heat, into a visible spectrum. Our findings show that the many of the windows and doors are in good condition, having been replaced fairly recently. However, we found that there are some areas of the building envelope that need improvement. These specific areas include some of the doors, and the roof.

Photographs 1a & 1b were taken in the front entrance of APW. To the naked eye, the door appears to have no thermal issues. The thermal imager, however, shows that there is roughly a 10^{o}F difference between the walls surrounding the door and the glass door itself. Looking at the thermal picture, the warmer temperatures are of the glass door are fairly uniform in color. That means that there is not one specific area that can be improved to fix the issue, such as weather stripping. One option however to fix this issue is to install an air-lock. The air lock would create a thermal environment of its own between the warmer inside temperature and the colder outside temperature.

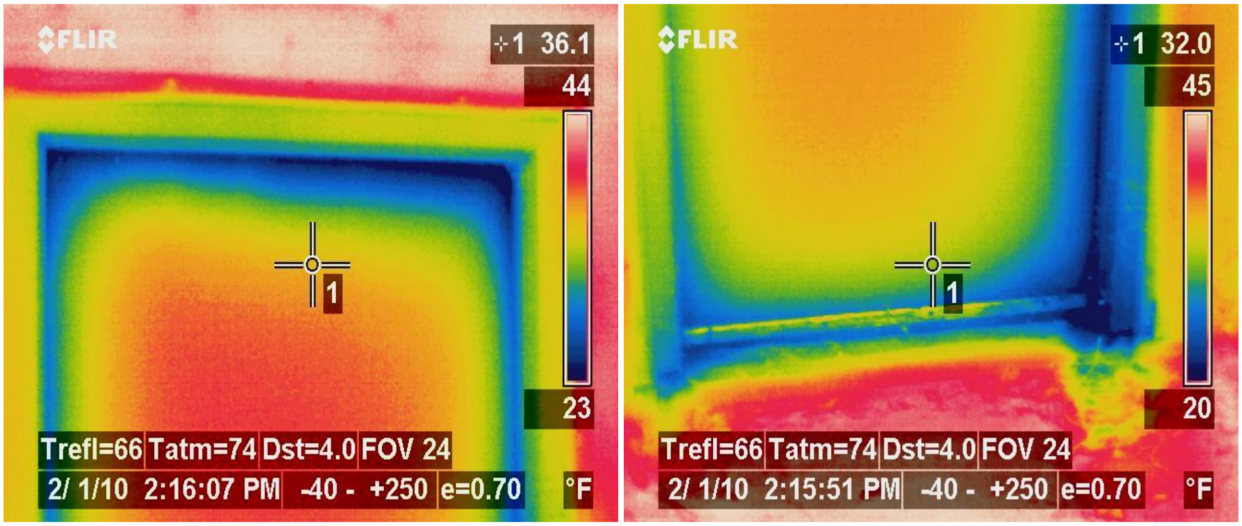

Figure 7: Thermal Images of Emergency Exit Door

The shots in Figure 7 were taken in the emergency exit stairwell, which leads outside. Of note are the thermal patterns visible around the door frame on the exterior door leading to the street. The dark blue areas are the areas where the coldest spots are. This is especially evident at the bottom of the door, because the door is not sealed properly. Looking at the warmer center of this door shows that the door itself is not in bad condition; however, it is severely lacking around the edges. If this door was re-hung correctly and weather-stripped (which involves placing rubber strips around the edges of the door) to make proper contact around the door frame, the thermal efficiency of the door would greatly increase.

Figure 8 depicts a properly-sealed door. This door leads to the emergency exit corridor. The color is much more uniform thoughout the door, meaning that there is minimal thermal "leakage." In addition, the frame and walls around are very similar in color, meaning they are the same tempertature. This is an ideal model of what the doors thoughout the building should look like. Replacing, repairing, re-hanging, and weatherstripping doors to model this one will

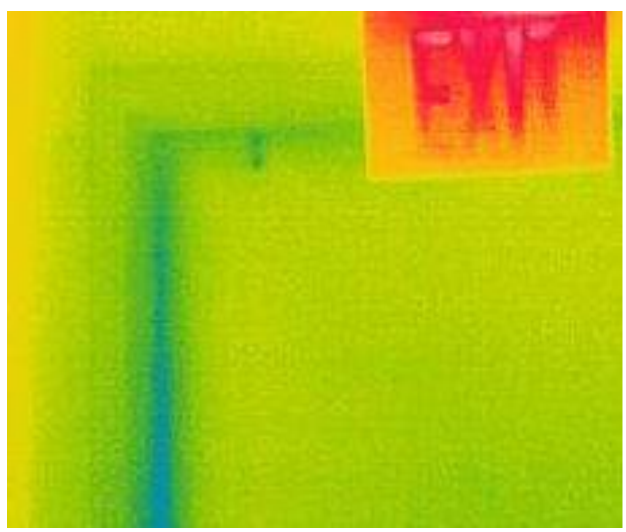

Figure 8: Properly Sealed Door

greatly improve the thermal effiency of the building by reducing costly thermal leakage and allowing for a more consistent ambient temperature throughout the building.

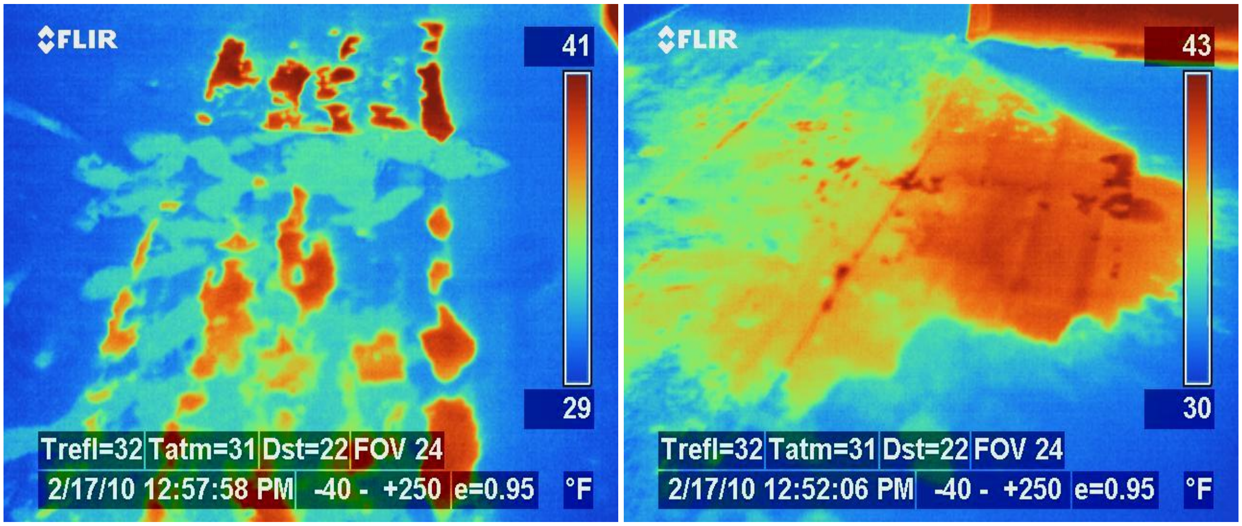

Figure 9: Rooftop Pictures (with snow present)

The photographs in Figure 9 were taken on the roof over APW's office space. These pictures were taken Febuary 17, 2010 at 1:00pm. The mean temperature that day was 27^{o}F with overcast conditions. In addition, it had snowed the previous day. These pictures show a very clear 12^{o}F difference in temperature between the snow covering the roof (blue) and the roof itself (red), where snow had already been melted by the heat leaking through the insulation. The roof was observed to have no snow left less than a week later on Febuary 23, 2010. In many buildings, there are policies prohibiting roof access during the winter months due to the danger of the ice that remains atop a properly insulated roof though the season. We observed at APW that, because of the roof's poor insulation, no such policy is needed.

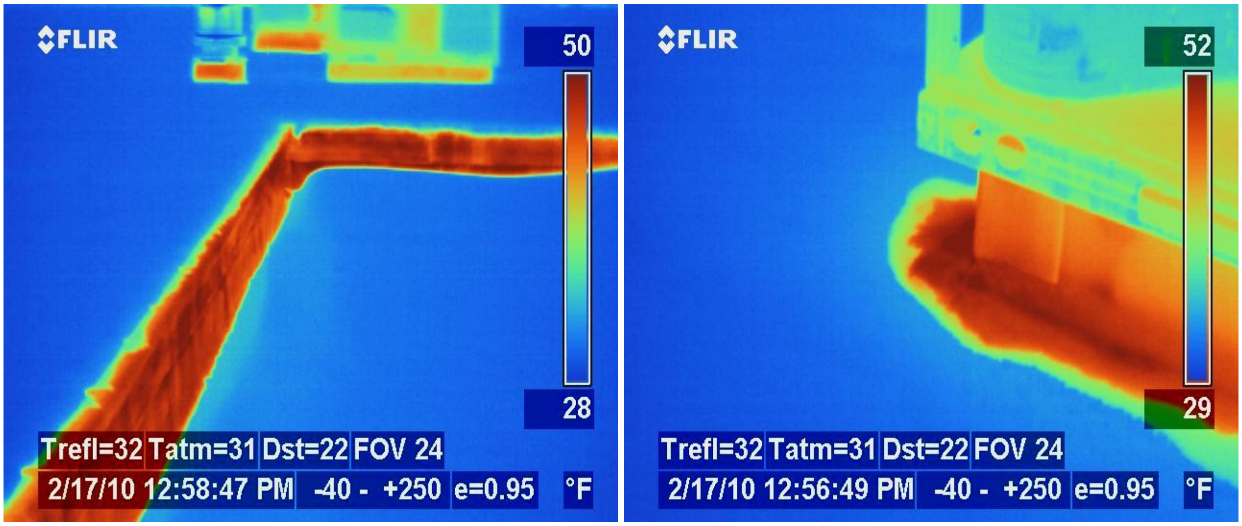

Figure 10: Specific Thermal Leaks on APW Roof

Photographs in Figure 10 were also taken on the roof of the APW building. The left depicts a 1-foot drop to a lower section of the roof directly over the APW offices. The measured temperature of this particular area was ~50°F. That is a 20°F difference between the snow on the roof and this exposed surface. The picture on the right shows the area surrounding one of the HVAC units. The difference in temperature here is even greater. In addition to thermal leakage, this particualr area is located directly above one of the water leaks that AIDS Project Worcester experiences in their building during heavy rain periods. Figure 11 shows one of the most severe temperature differences we observed while inspecting the roof. The temperature of the exposed tar is 30°F higher than the temperature of the surrounding snow.

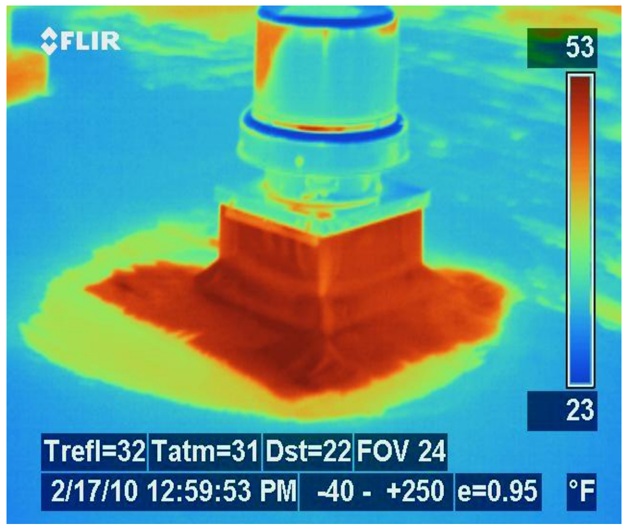

Figure 11: Thermal Leak Surrounding Fan Vent

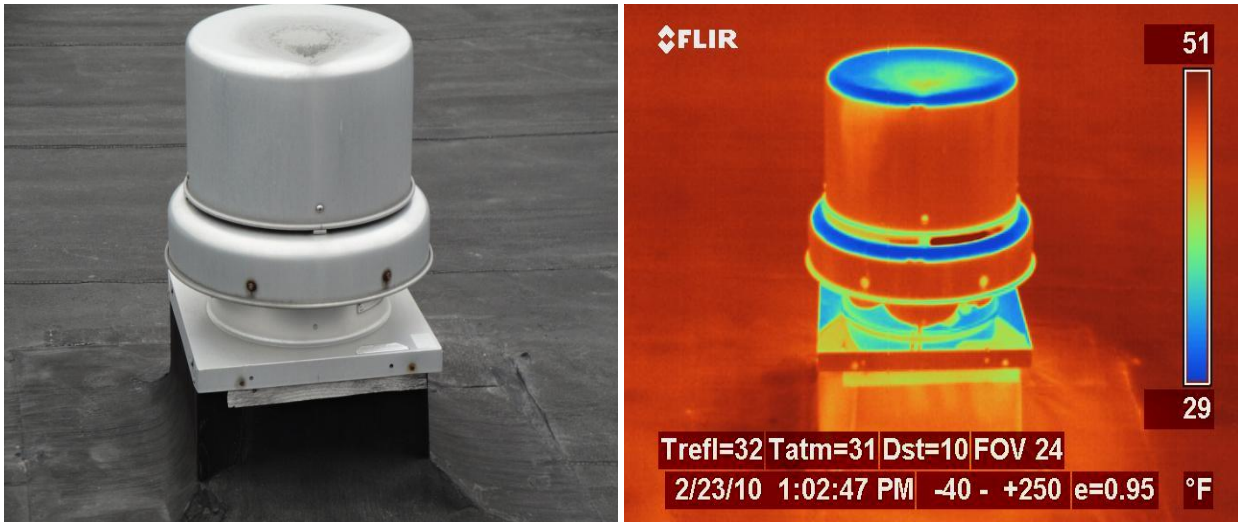

Figure 12: Thermal Images of Rooftop Thermal Leaks: Exhaust Vent

The photographs in Figure 12 were taken on February 23, 2010 at 1:30pm. The average temperature that day was 33^{o}F. These pictures were taken less than one week after the roof was covered with snow. In its hottest spots, the roof temperature reaches 51^{o}F which is less than 20^{o}F from the interior ambient temperature of 70^{o}F.

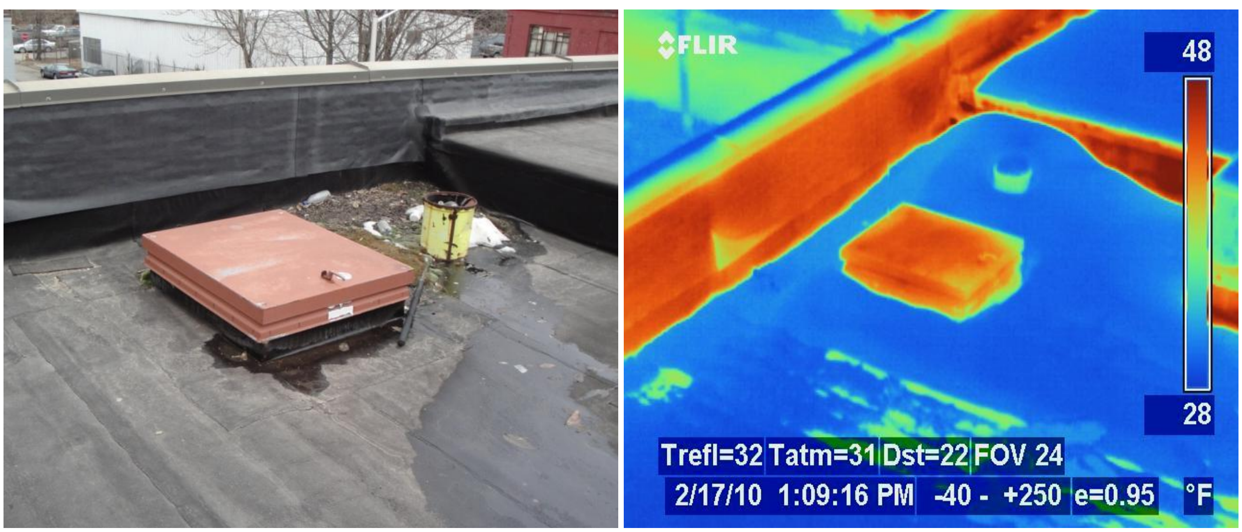

Figure 13: Thermal Images of Rooftop Leaks: Roof Hatch

One thing often overlooked when insulating a roof is the access hatch. As you can see in Figure 13, the hatch is much warmer than the snow covered roof. One option to reduce some heat loss is to fill the hatch-way with insulation. This particular hatch is locked from the inside and not used by APW, so it would be simple to seal off and properly insulate.

4.2.2 Recommendation: Building Envelope Improvement

We recommend that AIDS Project Worcester weather strip the doors that show thermal leakage, like the emergency exit door. While the front door does not exhibit thermal leak patterns, an option for APW to reduce heat loss through it is an air lock. An air lock will reduce the rate of heat transfer through the door when it is closed and it will keep warm air inside the building when people go in or out of the building. These two changes could significantly reduce heat loss.

Our findings clearly show that the roof is a major cause in the heat loss of the building. Thus, we recommend that AIDS Project Worcester proceed with roof replacement. This will not only reduce heat loss but could also allow APW to prepare for a green roof installation in the long run.

Our research narrowed down the list of new roofs to the three most common types: "Asphalt roll roofing, multiple-ply or built-up roofing (BUR), and flat-seamed metal roofing" (www.sacredplaces.org). Installing a flat-seamed metal roof would be the best option for APW. Metal roofing is very easy to install and also provides good insulation. It is also a good choice for green roof because a metal roof reflects most of the light. A greater light intensity is beneficial to the plants and grass in the green roof. The only downside to this is the high installation and maintenance costs involved with metal roofs. The owner will have to protect the metal roof from corrosion and acid rain. The NewEnglandandmetalroof.com estimates the cost of base installation between $12,750 and $16,500.

We were able to identify some companies that are in the business replacing roof. Most of the companies will provide a free inspection followed by their cost estimation of the roof replacement. The limited time in our project did not allow us to get a company to evaluate the roof, so we recommend APW to contact a company and carry out a roof replacement inspection at their own leisure. Two of the attractive choices of companies that provide metal roof replacing services are Interlock Metal Roofing, and New England Metal Roof. We recommend contacting them for a quote.

4.2.3 HVAC Operation Findings

One part of our energy audit was to monitor the temperature in HVAC ducts for each zone simultaneously. Our goal was to determine when the HVAC systems were operating and, more importantly, how they were working in relation to the other units. We found that the HVAC systems were working harder to heat the building at night, when no one was in the building, than they were during the working day. We estimate that heating costs could be reduced by 60%, or roughly $1800 per year by upgrading the thermostats and programming them correctly. The following sections discuss the problem and our proposed solutions in detail.

The HVAC systems at APW are in a state of disarray. The data we collected over 8 consecutive days of monitoring temperature in the HVAC ducts leads us to come to the conclusion that the HVAC controllers are either malfunctioning, incorrectly programmed, or have been compromised in some other way. We have extensive data to represent this claim.

Ideally, the HVAC settings in any building are managed to create unity in operation among all the units. In a space like APW, which employs six separate units to heat and cool their offices, harmony in operation is paramount to reducing energy waste and subsequently reducing energy costs. APW is divided into two areas by two spring-closed doors. Each of the two areas has 3 HVAC units to heat the space. Because the space is shared between each of the three units (i.e. there are no solid boundaries, like doors or walls that separate the vents), synchronization of the systems is the key to efficiently heating the space. If one unit is turned off and the other two are running to bring that space up to a certain temperature, the running units must operate for a longer period to make up for the non-operational unit.

Fig. 14 clearly shows the discrepancy in operation between two HVAC units that heat the same space. Shortly after the Zone-2 unit shuts down (at roughly 2:00 a.m.) after having run though the night, the zone-1 unit begins to heat the same space for the rest of the working day. Then, just as zone-1 is shutting down at the end of the work day (roughly 4:20 p.m.) zone-2 turns back on to heat the building throughout the night again, while no one is there.

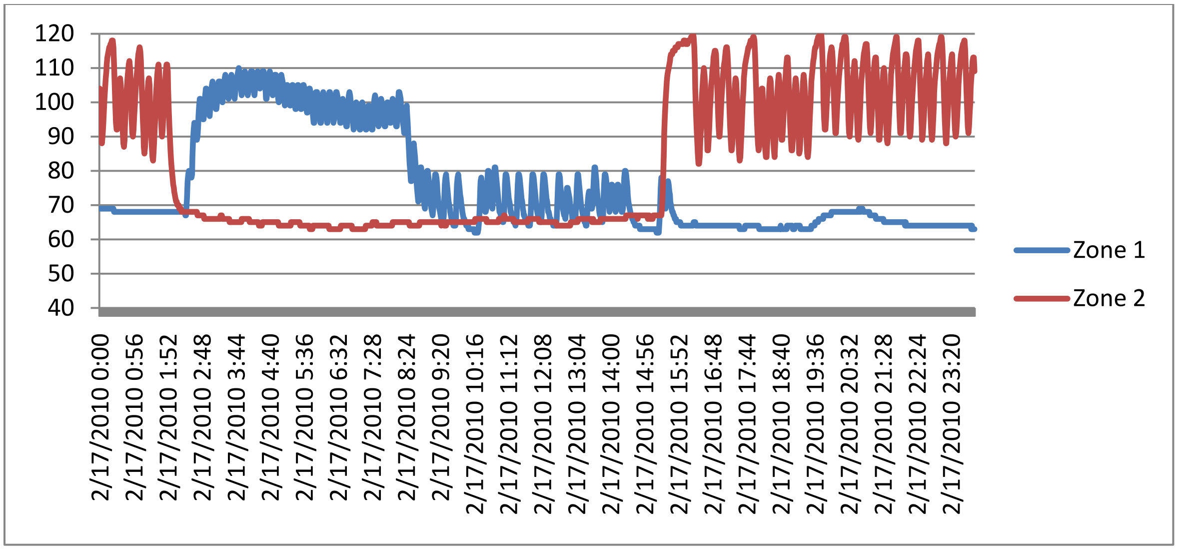

Figure 14: Temperature data for Zone 1 and Zone 2 over a 24-hour period, 2/17/2010

Discrepancies like this appear very frequently in the data that we collected. In fact, using our temperature-to-energy-cost algorithm, we determined and estimate of the cost breakdown of the HVAC system, found in Fig. 15.

Figure 15: Cost Breakdown for HVAC Operation Over an 8-day Period

We estimate, as shown above, that only $53.26 or ~25% of the total heating cost incurred over the 8-day recording period was used to heat the building during normal working hours. Not only is that a small portion of the total cost, but also we estimate that it is insufficient to effectively heat the building.

Using the data collected from the newer, EnergyStar-certified thermostat that controls one of the six thermostats, we used its operation, which was much more consistent than the other thermostats, to develop an estimate for optimal HVAC operation. We estimate that if the thermostats are programmed to begin heating at roughly 7:00 a.m. and maintain a 70^{o} F temperature until 5:00 p.m., the total cost of such an operation would be roughly $85 for an 8-day period. That is 60% less than the estimated cost during the period we measured.

Another issue with the current thermostat setup is the need to access them on-site. We found this to be an issue on Wednesday, Feb. 24th, which was a snow day closure for APW. Fig. 16 shows (messily) the HVAC operation on that particular day.

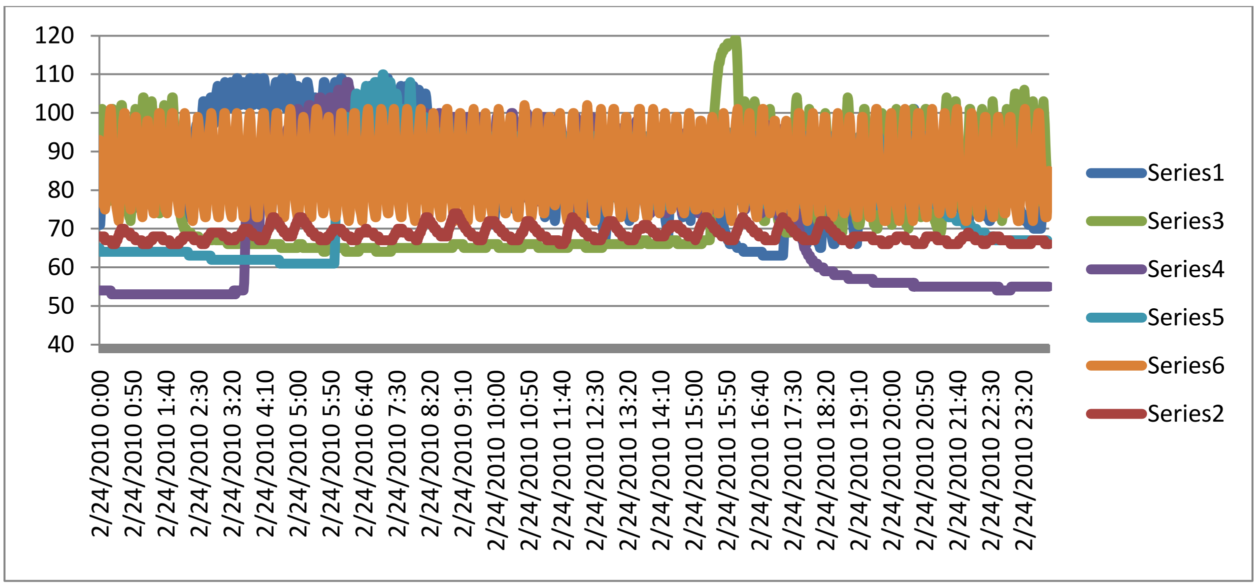

Figure 16: HVAC Operation in all zones, 2/24/2010

The graph in Fig. 16 is difficult to read because there is so much HVAC activity that the lines blur together. We estimate that this day alone cost APW roughly $27.80 in natural gas. Unscheduled closures can account for considerable expenses in wasted energy. While we would not suggest that any staff member brave inclement weather or dangerous conditions just to save $30, these wastes can be significantly reduced by thermostats that can be controlled remotely.

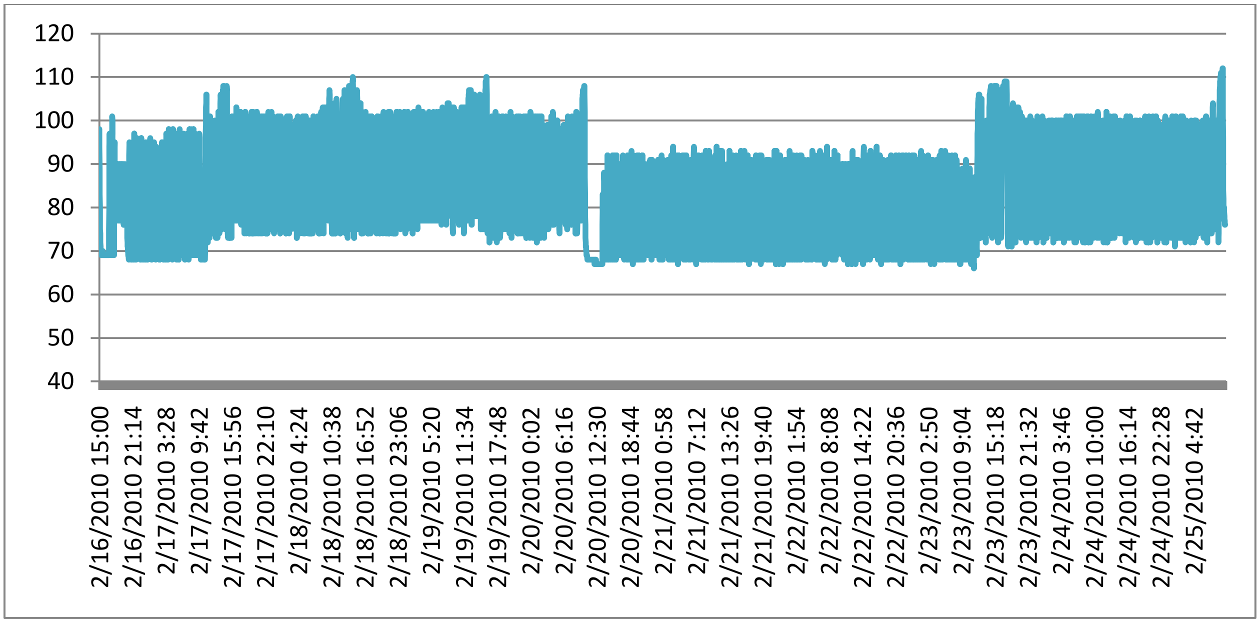

Figure 17: Training Room HVAC Unit Operation Over 8 Days

The final finding of note is the HVAC unit dedicated to heating the training room at APW, which is the largest room in APW's portion of the building. This unit is unique from the others firstly because it is electric instead of gas and secondly because it is the only unit controlled by an analog, non-programmable thermostat. Next to this thermostat reads a sign: "Please do not turn off this thermostat. It will cause an imbalance in our heating system!" Fig. 17 shows the result of this policy over our full 8-day period.

The cost breakdown for this unit was slightly more difficult than the others because it is electric. However, the system is rated to draw 6 kW during operation. Because it cycles on and off constantly over generally equal time intervals, we estimate that over a given 24 hour period this unit is on for about half the day, or 12 hours. 12 hours of operating a 6 kilowatt unit means 72 kWh consumed over the course of one day. The cost of 72 kWh is roughly $11.23. This machine could be drawing over 2000 kWh per month while it is in constant operation. 2000 kWh is roughly 20% of APW's electricity consumption in a given month, translating to about $330 in electricity costs. While these calculations are rudimentary and probably overestimate the actual cost of running this unit, it is clear that running this machine constantly is not an efficient policy and could be costing APW a large amount of money.

In summary, we estimate that APW could save 60% of their heating costs by fixing the apparent issues with the HVAC system translating to roughly $1800 per year in heating alone. It is critical to note there is significant potential to realize further savings during the summer months because the dysfunction shown by the HVAC system in heating the building probably carries over into cooling as well.

4.2.4 Recommendations: HVAC Units and Thermostats

First, we recommend limiting general access to the thermostats. This recommendation is simple and is geared towards reducing accidental human error when modifying thermostat settings. The procedure for limiting access can range from a "please do not touch" policy for staff to installing locked cases around each thermostat.

We also recommend reprogramming the thermostats or having them reprogrammed by a professional as soon as possible. Much of the energy waste in the system could be eradicated by synchronizing the time and operation schedules of all the thermostats assuming they all are in functional order.

In addition to the above, we recommend installing automated thermostats. By using these new thermostats, APW could reduce waste by being able to remotely shut down their HVAC units in case of unexpected closure. A building automation system would also ensure that all the times are synchronized across multiple thermostats and is capable of managing the units correctly to quickly and efficiently heat the building.

In our background, we discussed two different thermostat systems that offer important features to help reduce energy waste during non-working hours and preserve uniformity in operation across a multi-unit HVAC system. One was a more residential-oriented system made by Ecobee, and the other was a commercial-grade building automation system made by Net/X. after researching these two systems in relation to the problem, we would like to officially recommend the Net/X system for APW's building.

The Net/X system is significantly more expensive than its Ecobee counterpart. We believe that this cost is justified by the advanced features and focus on reliability and consistency in the system. While Ecobee's software is more visually pleasing and they offer an iPhone app capable of controlling the HVAC system remotely, it is difficult to determine how well such a system will function in a commercial building. One potential problem is the wireless internet; there is a distinct possibility that one or more of the thermostats in APW are outside the range of their wireless network. Without an existing wireless network, those units lose the remote control functions that make them uniquely useful.

The Net/X system relies on its own method of wireless transmission which comes at a significant price premium. This transmission protocol, however, is tested to range 1,000 feet in every direction. Coupled with the relaying capabilities that every thermostat has, the Net/X thermostats would never be out of range of their central controller.

Expandability is another strong suit for the Net/X controllers. The Ecobee software limits the number of thermostats to be controlled simultaneously at 6. For APW, that means that only their 6 existing thermostats would be eligible for replacement. The Net/X system is limited to 16 thermostats, which opens up possibilities for expansion. In our initial interview with Director McKee, he expressed a desire to be able to directly contribute to the businesses and buildings surrounding APW. One way they could potentially do that would be to have the thermostats in the Habitat for Humanity and/or AllCare Pharmacy areas of their building replaced and centrally controlled by the system as well. Each thermostat can be set to its own unique schedule, and as long as the three different schedules could be coordinated and entered into the Net/X software by the staff, all three co-tenants of the 85 Green St. building could see significant benefit from the system.

While the Ecobee software has built-in remote access to the system, Net/X can be accessed remotely by typical remote-desktop software. Some APW staff members are familiar with remote desktop and use LogMeIn software to access their work computers from home. Remotely accessing Net/X through LogMeIn would be the same as accessing it on site, and would allow a staff member to turn off the heat or change the heating/cooling schedule without having to be present in the building.

The cost of the wireless Net/X system, made by Network Thermostat, is $3300 at retail prices. Network Thermostat offers special pricing for non-profit organizations to get the equipment, but installation is an additional cost. For installation, we recommend contacting Mr. Bafaro, the building owner, who is an HVAC specialist. If Mr. Bafaro would be willing to donate the time for installation or at least offer a reduced rate, then even at the full retail price of $3300, we estimate the maximum payback period of the system to be roughly two years considering heating costs alone; savings during the summer on cooling could halve that.

Lastly, we recommend that the HVAC units themselves be tested for efficiency. The rooftop units have a claimed efficiency of 80%, and they are over 20 years old. Because of their age, there is a good chance that they are operating at a lower efficiency than they were when new. Testing HVAC units is not something we were capable of doing because of the specialized tools and expertise required, but we recommend one of two possible ways to have this done. One is, again, Mr. Bafaro. He probably has not given the HVAC units of the 85 Green St. building much thought. However, we believe that asking him to examine the system may fall within general building maintenance. Testing HVAC units may not be his specialty, however.

We contacted an HVAC engineer, Thomas Donahue, to get a quote for testing the HVAC systems. He said it would cost “less than $1,000” and he would test the HVAC system and produce a list of recommendations for reducing energy consumption. NSTAR, APW’s gas utility provider, will reimburse the cost of his service if APW agrees to implement his recommendations.

In summary, APW’s HVAC system is not functioning optimally, and is using far more energy than it needs to heat the building. Our recommendations offer ways for APW to both reduce these costs and increase the thermal comfort level in their building. We estimate that implementing our recommendations will save roughly 60% of their natural gas costs ($1800 annually) and could save 20% of their electricity costs during the winter months ($1350.31 annually). These estimates do not include potential savings on cooling the building, which could conceivably double the savings.

4.3 Long Term

4.3.1 Green Roof

We recommended that APW contact contractors or structural engineers to implement a green roof. A contractor or structural engineer will be able to design and plan a green roof that would be suitable for APW. In our research for green roofs, we discovered www.greenroofs.com, which has a directory of manufacturers, suppliers, and professional services. Through our research we also discovered Apex Green Roofs, a green roof company based in Massachusetts. We believed this would be a good starting point for APW if they decide to move forward with installing a green roof.

4.3.2 Solar Panels

Our last recommendation is a solar power installation. To determine APW's eligibility for solar power, we asked Sunlight Solar, a local solar installer based in Newton, MA, to perform an evaluation of the building. They provided APW with a complete physical and financial assessment of the feasibility of solar at 85 Green St. This recommendation summarizes that data for APW.

Sunlight Solar's proposed installation is capable of providing for 12% of APW's electrical demand based on their electricity usage for 2009. The cost of the installation is roughly $81,612 and would save about $3,591 per year. Fortunately, APW would not have to pay the full cost; federal and state funding sources reduce that cost by ~$55,000. Sunlight Solar guarantees that their customers in Massachusetts will receive the state-backed Massachusetts Technology Collaborative Renewable Energy Trust rebate, which is equal to $1.50 per watt of any solar installation. Sunlight Solar's analysis included a 13,230 kW system, which returned a rebate of $19,845.

Besides the $3,591 in annual electricity savings, solar panels generate Renewable Energy Credits (RECs) that can be sold separately from the electricity that the panels provide. Sunlight Solar estimates that the sale of these credits would generate roughly $4,653 per year. For more information on RECs, see Appendix D.

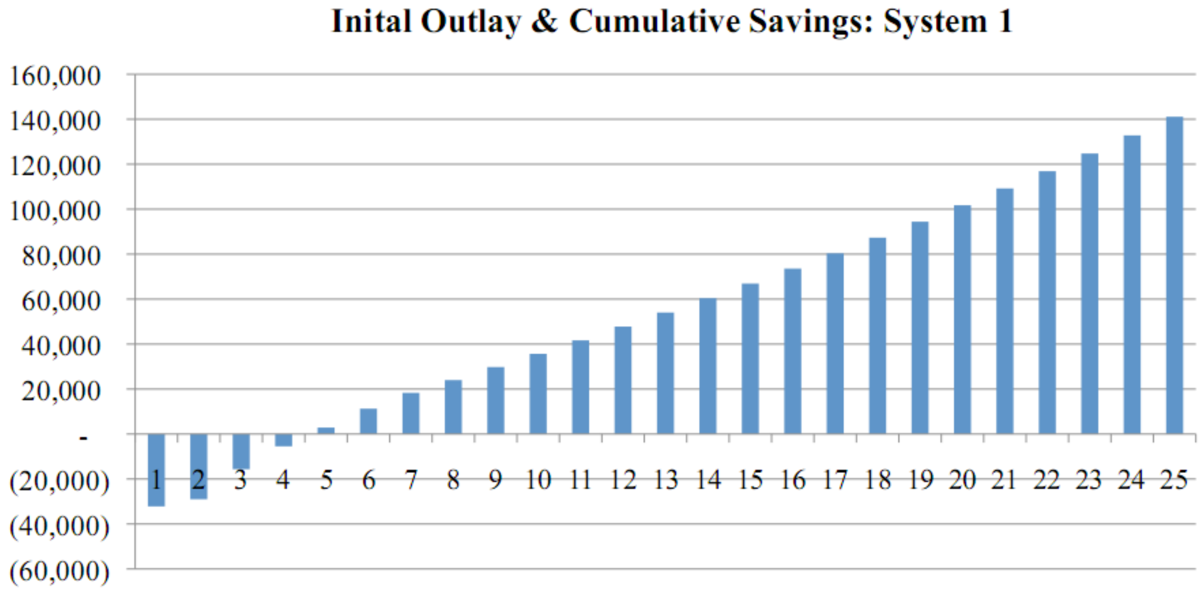

Figure 18: Cumulative Savings for Solar Installation over 25 years

The federal funding for the system comes in the form of a tax credit or grant. The Federal Business Energy Investment Tax Credit (ITC) offers a 30% tax credit on the total cost of a solar installation with no upper limit. It is also possible to get this rebate in the form of a grant instead of a tax credit. The value of this 30% credit to APW's installation would be $24,483, further reducing the installation cost. While Sunlight Solar guarantees the MTC rebate, securing the federal incentive would be up to APW (or Mr. Bafaro). With both of these funding sources lowering the installation cost to $37,284, the estimated payback period is 5 years. Over a 25-year period, the total savings on electricity and the sale of RECs would amount to just over $140,000, as shown in Fig. 6. The complete Sunlight Solar assessment can be found in Appendix D.

We have already discussed the primary funding sources available for a solar installation above. We recommend that Mr. Bafaro initiate the solar installation because he is more readily eligible to receive Federal ITC credits. If APW has the capital to pay for the units themselves, they could initiate installation through Mr. Bafaro by proxy, and would probably need to renegotiate their lease to account for the value the panels add to the building.

If APW does not have the capital to finance the installation, there is another alternative. In our background we discussed PPA agreements, where a third-party purchases the panels and sells the electricity to the building tenants at a reduced rate and sells the RECs to make money.

This installation could be a business proposition to Mr. Bafaro, where he would pay for and own the panels and sell the electricity they generate to APW at a predetermined, highly reduced rate. Mr. Bafaro would also be able to sell the RECs and pass on a percentage of the money made from that on to APW. Sunlight Solar will be an excellent resource for working through the details of an arrangement like this.

In summary, a solar installation could save APW over $140,000 over a period of 25 years. A PPA agreement with Mr. Bafaro would save APW less money, but would require little to no up-front cost for APW. We recommend presenting these options to Mr. Bafaro to see if he is willing to help APW reduce their energy costs with a clean and renewable energy generation system.

4.4 Funding Sources

For our project, we also researched funding sources that would make our medium term and long term recommendations more feasible to implement. The following table summarizes our funding sources for our medium and long term recommendations:

Medium-term:

Fund Name	**Technology and Amount**	**Criteria/recipient**
Tax Incentives Assistant Project (TIAP) (http://energytaxincentives.org/)	heating, cooling, ventilation, water heating, and interior lighting- up to $1.80 per square foot	Building owner (taxpayer)
National Grid- Small/mid-sized business energy efficiency loan/rebate program	Lighting, lighting controls/sensors, programmable thermostats- 70% of project costs can be paid through a rebate. The remaining 30% can be financed by National Grid with a 0% interest loan, with a payback time of up to 24 months	Commercial
AIDS Project Worcester	All technologies- depends on amount raised	Not required
Green Communities Grant (http://www.greencommunitiesonline.org/tools/funding/grants/)	Green construction items, energy service costs, $20,000-75,000	Non-profit
The Home Depot Foundation (http://www.homedepotfoundation.org/index.php)	“Greening” projects- amount unknown	Non-profits and building owners

Long-term:

Fund Name	Technology and Amount	Criteria/recipient
New Generation Energy- Community Solar Lending Program*	Photovoltaics- $5,000-100,000	Commercial, non-profit, loans up to 1-10 yrs. Rates vary 0-5%
Mass. Renewable Energy Trust- Commonwealth Solar II Rebates*	Photovoltaics- Residential: $10,500; Commercial: $5,500 (per host customer), up to $250,000 per parent company.	Commercial, non-profit
The American Recovery and Reinvestment Act- Commonwealth Solar Stimulus*	Photovoltaics- $162,500	Commercial, non-profit
Business Energy Investment Tax Credit (ITC)*	Solar- no limit	Building owner (taxpayer), commercial
U.S. Department of Treasury*	Solar- 30% of property that is part of a qualified facility, qualified fuel cell property, solar property, or qualified small wind property 10% of all other property	Commercial
USDA- Rural energy for America Program (REAP) Grants*	Solar and other efficiency technologies not identified- varies	Commercial
Green Communities Grant (http://www.greencommunitiesonline.org/tools/funding/grants/)	Green construction items, energy service costs, $20,000-75,000	Non-profit
The Home Depot Foundation (http://www.homedepotfoundation.org/index.php)	"Greening" projects- amount unknown	Non-profits and building owners
U.S. Department of Energy Loan Guarantee Program*	Solar- amount varies	Non-profits and commercial

* http://www.dsireusa.org/incentives/index.cfm?State=US&ee=1&re=1

Conclusion

The goal of this project was to assess AIDS Project Worcester's facility and operations and produce technological and behavioral recommendations to lower their energy costs over short, medium, and long terms. Our project culminated into our short, medium, and long term recommendations. In the short term recommendations, we recommended AIDS Project Worcester limit the use of space heaters and temporarily promote the use of wearing sweaters in winter months. The "sweater policy" should be unnecessary once the HVAC units are working effectively. We also recommended the use of timers on space heaters and changing the computer policy to allow for shutting them down at night. Also, wake-on-LAN can enable APW staff to remotely access their computer even when they are shut down or on standby. Lastly, we recommended that APW staff turn off their hallway lights when they lock their building.

For our medium-term recommendations, we recommended restricting access of thermostats to the general staff and also getting professionals to reprogram the thermostats. We also recommended installing new thermostats from Net/X. APW should also test their HVAC units for efficiency. Lastly, we recommended that APW evaluate the idea of roof replacement by firstly getting its roof inspected by Interlock Metal Roofing, New England Metal Roof, or another roofing company.

In our long term recommendation, we recommend that APW contact contracts or structural engineers to install a green roofs. We also recommend that APW install solar panels to which would drastically reduce their energy cost in the long run. We estimate that APW will save around 24% of their energy costs if they carry out our recommendations. The following chart summarizes the estimated savings of APW's energy with the short, medium and long term recommendations:

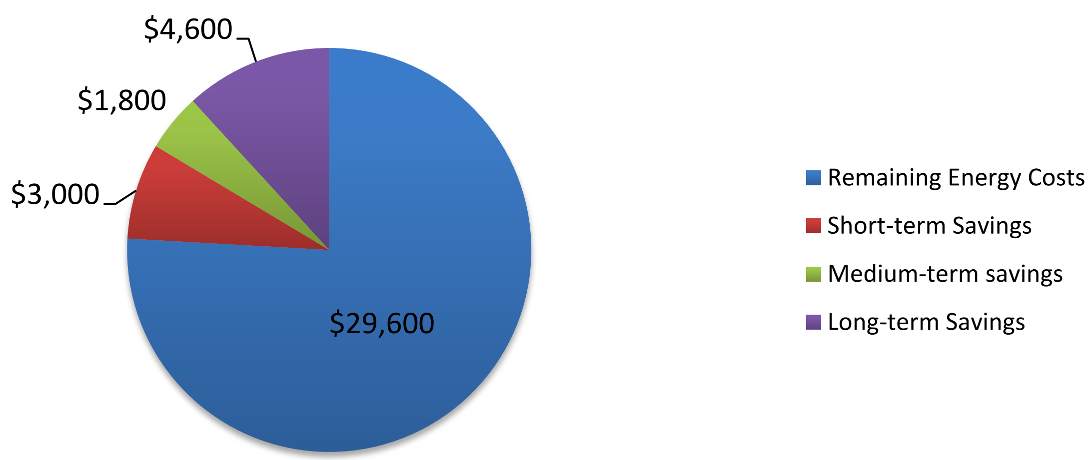

Figure 19: Total Savings

If APW proceeds with our recommendations, it will definitely save them a large sum of money, but technological improvements alone can only provide them so much. The proper use of these technologies is a huge part of our recommendation. Thus, raising awareness in the staff about these technologies was also part of our project. We did this by conducting a poster walkthrough in which we put up 18 posters in APW hallway and had staff give us feedback on them. At the end, we picked the four best posters that was well-liked by the staff. The following table shows those posters and the comments that they received:

<table>
<tr><td>
</td><td>Pro:
• Love this one, resources are very limited
• Creative and displays a valuable message
• YES
• KOOL
Con:
• Ugly</td></tr>
<tr><td>
</td><td>Pro:
• I like very much
• Brings awareness, re: options (check plus) for consumption
• Love this
Suggestion:
• Background should be earth color</td></tr>
</table>

<table>
<tr>
<td>
</td>
<td>Pro:
• Like
• Like
• Good, simple
• I like the visual I’m all about the green
• Makes you think, a lot</td>
</tr>
<tr>
<td>
</td>
<td>Pro:
• Like
• Like this one, pretty cool
• Like this one <u>a lot</u>
• Makes one think, very good
• I like it
• Good message
Con:
• Ugly graphic</td>
</tr>
</table>

We hope that these posters raise energy conservation awareness throughout the staff. This will help AIDS Project Worcester not only become an energy efficient building but also a practitioner of energy conservation measures. In this manner, AIDS Project Worcester can become a model for the community in the implementation of energy-efficient technology and energy conservation practices to an existing building. We also hope that our project will open the doors for future IQP’s at AIDS Project Worcester. One of the projects could be to empower one or more staff members to monitor the efficiency of future technological implementation at APW. Another project could be to create a comprehensive manual on policy changes that will improve the behavioral practices of APW staff.

Our seven week time at AIDS Project Worcester was a lot of fun for the group. We enjoyed working with the staff members and love and respect their continued dedication to helping the community. We hope our recommendations will allow them to increase their capacity to do what they are passionate about.

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Materials specified: Publisher description http://www.loc.gov/catdir/description/mh023/97026079.html; Materials specified: Table of contents http://www.loc.gov/catdir/toc/mh022/97026079.html

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Appendix: A

Washington State University

Energy Audit Suggestions

Pre-Audit Worksheet

Energy Audit Checklist

Washington State University: Energy Audit Checklist Suggestions

Suggested O&M

- **Building Envelope**
    - Realign or re-hang doors that do not close properly.
    - Replace warn and/or broken weather-stripping and caulking
    - Keep curtains and drapes closed in unoccupied spaces
    - Before replacing water damaged insulation, repair roof
    - Verify that vapor barrier faces the conditioned space and is intact
    - Repair or replace damaged or missing shading devices
- **Building Occupancy**
    - Reschedule off-hour activities to accommodate partial shutdown of building systems other than ventilation systems
    - Reschedule custodial and cleaning activities during working hours whenever possible
    - Re-examine original assumptions regarding occupancy patterns and building usage. Modify patterns for increased energy efficiency.
- **HVAC – Controls**
    - reset thermostats to correct settings
    - Install or replace locking screws to prevent tampering
    - Install tamper-proof locking screws on thermostats
    - Adjust thermostats to 68¬oF in heating season and to 78oF during cooling season
    - Routinely check all time clocks and other control equipment for proper operation, correct time and day for the night and proper programming of on-off set points. Protect from unauthorized adjustment
    - Reduce thermostat settings by a minimum of 10oF at nights, for weekends and holidays during heating season, but maintain ventilation
    - Shutdown air conditioning units at night, on weekends and holidays.
    - Reduce winter thermostat settings to 55oF in unoccupied areas
    - Where possible, turn off heating systems if nothing; in space can freeze
    - Use spot heaters/coolers in large spaces with low occupancy
    - Increase summer thermostat settings, in unoccupied areas, if possible.
    - Experiment with start-up times and duration of operation to determine satisfactory comfort levels for occupants. Reduce or turn off heating and cooling during the last hour of occupancy, allowing the building to "coast"
- **HVAC**
    - Develop maintenance schedule for air filters and heating/cooling coils
    - Develop maintenance schedule for cleaning intake and output vents
    - Install filter pressure-drop gauges
- **Lighting**
    - Post instructions to turn off flights when leaving area
    - Assure wall switch times function properly

Suggested ECM

- **Building Envelope**
  - Consider adding reflective or heat absorbing film to minimize solar gain in the summer and heat loss in the winter
  - Insulate between heated/cooled spaces and unconditioned areas such as storage room leading to upstairs
  - Add new insulation to meet recommended standard
- **Building Occupancy**
  - Install an automated energy management system that will control all spaces in accordance with usage
- **HVAC – Controls**
  - Install programmable thermostats that support heating and cooling
  - Use automated energy management system
- **Lighting**
  - Rewire switches so that one switch does not control all fixtures in multiple work area
  - Provide timer switches in remote or seldom used areas where there will be brief occupancy periods.

COOPERATIVE EXTENSION
WASHINGTON STATE UNIVERSITY
ENERGY PROGRAM

Washington State University Energy Program
Energy Audit Workbook

Table of Contents

Please Print or Type

1. Building Information

Name of Institution	Address
Owner, if other than Institution	Address
Name of Building	Building #
Address (Street or P.O. Box)	City, State, Zip
Date of Audit	Type of Institution Public___ Private Non-Profit ____ Other ____
Building Manager (administrator responsible for bldg.)	Bldg. Mgr.'s Phone
Energy Management Coordinator (EMC) or Monitor	EMC's Phone
Person Completing this Audit (include Cert. #)	Phone
Building Type and Category School: __Element. __Second. __Comm.Coll. __Coll./Univ. __Voc. Tech. Ctr. __Other, Specify ____________ Hospital: __General __Psychiatric __Other, Specify ______________ Government: __Federal __State __City/County __Special Dist. __Indian Tribe Public Care: __Nurs. Home __Long-term care __Rehab. Center __Orphanage __Public Health __Res. Child Care __ Other, Specify _______________ Date of construction, If known _____________	Building Use ___Office ___Storage ___Library ___Services ___Police Station ___Fire Station ___Dormitory ___Prisoner Detention ___Other, Specify __________________
Original Architects (if known)	Original Engineers (if known)
Building Modifications or Changes In Use Anticipated in the next 15 yrs:	Remaining Useful life of the building: ____________Years
Does the Institution Have an ongoing energy management program?	___Yes ___No
Previous Energy Audits Completed? (if yes, give dates) __Yes __No Dates ________________ ____________________ ________________ __________________	
Previous Architectural/Engineering Studies Undertaken? (if Yes, Specify) ___Yes ___No	
Name of Electric Utility	Is this building on the National Historic Preservation Register? __Yes __No

1. Building Information

Energy Saving Operation and Maintenance Procedures Implemented or Under Consideration Prior to this Audit (specify which). Please include an estimate of implementation cost and energy savings in kWh/yr and Btu/yr.
Conservation Measures (retrofit) Already Implemented or Under Consideration Prior to this Audit (specify which). Pleas Include Estimate of Cost and Savings if Available.

1. BUILDING INFORMATION

Building Occupancy Profile

100% Daily Profile

0% 12 mid 6 am 12 noon 6 pm 12 mid

100% Weekly Profile

0% Sun. Mon. Tues. Wed. Thurs. Fri. Sat.

100% Annual Profile

0% Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sept. Oct. Nov. Dec.

Building Occupancy Schedule

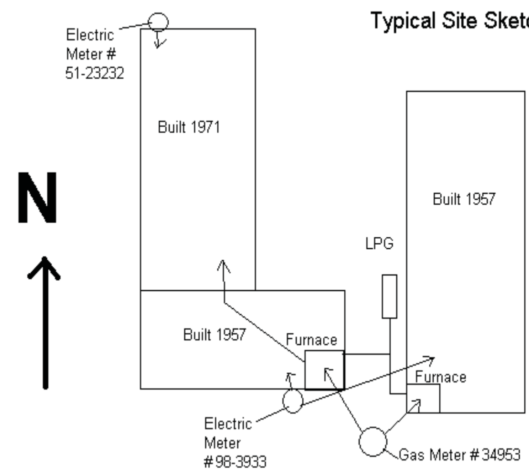
Area/Zone	# of Sq.Ft.	**Week Days**			**Weekends, Holidays**		
		hours		# of People	hours		# of People
		from	to		from	to	

BUILDING INFORMATION

On the following page, prepare a site sketch of your building or building complex which shows the following information:

1. Relative location and outline of the building(s).
2. Building Age
3. Building Number (Assign numbers if buildings are not already numbered.)
4. Building Size
5. Fuel Type
6. Location of heating and cooling units
7. Heating plants
8. Central cooling system, etc.
9. North orientation arrow

Typical Site Sketch (Example)



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2. BUILDING CHARACTERISTICS

a. **Gross Floor Area**: ______ Gross Sq.Ft. x Ceiling Height _______ Ft. = volume ____Cu.Ft.
b. **Conditioned Floor Area**: _______ (if different that gross floor area)
c. **Total door Area**: __________ Sq.Ft. Glass doors _______sq.ft. Wood doors _____sq.ft.
Metal doors _______ sq.ft. Garage doors ________ sq.ft.
d. **Total Exterior Glass Area**: __________sq.ft. Single Panes _______sq.ft. Double panes ____sq.ft.

	North	South	East	West
Total Area	________sqft	_________sqft	________sqft	_________sqft
Single Pane	________sqft	_________sqft	________sqft	_________sqft
Double Pane	________sqft	_________sqft	________sqft	_________sqft

e. **Total Exterior Wall Area**: ___________ sqft Material: [ ]Masonry [ ]Wood
[ ]Concrete [ ]Stucco [ ]Other
f. **Total Roof Area**: __________sqft Condition: [ ]Good [ ]Fair [ ]Poor
g. **Insulation Type**: __________Roof ____________Wall ______________Floor
h. **Insulation Thickness**: __________Roof ____________Wall ___________Floor
i. **Metering**: Is this building individually metered for electricity? [ ]Yes [ ]No
Is this building individually metered for natural gas? [ ]Yes [ ]No
Is this building on a control boiler system with other buildings? [ ]Yes [ ]No

j. **Describe general building condition**:

SITE SKETCH

Indicate compass direction with a north arrow.

2. ANNUAL ELECTRIC USE AND COST

Include Electrical Demand, if applicable

Building	Address	Year of Record From / To
Account Number	Meter Number	Utility
Maximum kW Demand W/O charge	Minimum Power Factor W/O charge	Building size (sqft)

1	2	3	4	5	6	7	8	9	10
Meter Read Date From	To	KWh* Used	KWh/gross sq.ft. **	Annual (EUI) BTU/sqft (000)	Energy Cost	KW-KVA Demand	Fixed Service Cost	P.F. * and Demand Cost***	Total Cost
TOTAL									

Comments:

Conversion: 3413 BTU/kWh
*KW – Kilowatts, KVA – Kilo-Volt-ampere, KWH – Kilowatt hour, P.F. – Power Factor
**Total annual kWh divided by the building's gross sq. ft.
***If demand and/or power factor are metered and billed, energy cost here.

3. ANNUAL NON-ELECTRIC ENERGY USE AND COST

Photo copy this form for additional fuel types

Building	Address	Year of Record From To
Account Number	Meter Number	Utiilty
Building Size (sq ft)	Fuel Type	Specify Units

Billing Period From	Billing Period To	Fuel consumption	Conversion Factor	MMBTU	Annual (EUI) Btu/sq.ft.	Cost $
TOTAL						

Comments:

***Conversion Factors**

Natural Gas	100,000 Btu/therm
Natural Gas	1,030 Btu/cubic feet
Liquified Petroleum	(LP bottled gas) 95475 Btu/gallon
Kerosene	134,000 Btu/gallon
Distillate Fuel Oil	138,690 Btu/gallon
Residual Fuel Oil	149,690 Btu/gallon
Coal	24.5 million Btu per Standard short ton
Wood	8,680 Btu/pound
Steam	970 Btu/pound
Other	Consult standard Engineering Reference Manual

4. **HEATING PLANT**

	PRIMARY	SECONDARY1	SECONDARY2
(A) System Type Code	_________	_____________	_____________
How many each type?	_________	_____________	_____________
Rated Input Consumption	_________	_____________	_____________
Rated Output Capacity	_________	_____________	_____________
(B) Energy Source Code	_________	_____________	_____________
(C) Maintenance Code	_________	_____________	_____________
(D) Control Code	_________	_____________	_____________

(A)System Type Code

1. Fire tube-Steam
2. Water tube-steam
3. Fire tube-hot water
4. Water tube-hot water
5. Electric Resistance
6. Heat pump with aux. Elec.heat
7. Purchased steam
8. Other (explain)

(B)Energy Source

1. Natural Gas
2. LP Gas
3. #2 Fuel Oil
4. #4 Fuel Oil
5. #6 Fuel Oil
6. Electricity
7. Coal
8. Wood
9. Solar
10. Purchased Steam

©Maintenance Code

1. Good
2. Average
3. Fair
4. Poor

(D)Control Code

1. Manual
2. Somewhat automated
3. Highly automated

Operation Profile:

___________hrs/weekday _____________hrs/Sat. ______________hrs/Sun. ___________wks/yr

Estimated annual hours of operation _______________

From (month) _____________ through (month) ______________

Thermostat set points:
Day: ________________
Night/weekends: _________________

Heating Degree Days: ____________________ (see table on page 15)

Comments:

5. HVAC DISTRIBUTION SYSTEM

Area Served (sq.ft.)	Location of Unit(s)

	PRIMARY	SECONDARY1	SECONDARY2
A. System Type Code	________	____________	____________
B. Maintenance Code	________	____________	____________
C. Control Code	________	____________	____________

(A) System Type Code
1. Single Zone
2. Multi Zone
3. Dual duct
4. Variable air volume
5. Single duct reheat
6. 2-pipe water
7. 4-pipe water
8. Window unit
9. Unit ventilator
10. Fan Coil
11. Unit heater
12. Other (define)

(B) Maintenance Code
1. Good
2. Average
3. Fair
4. Poor

(C) Control Code
1. Space thermostat
2. Outside temperature sensors
3. Time clocks
4. Energy management system
5. Auto supply temp reset
6. Economy cycle
7. Heat recovery
8. Other (define)

---

6. COOLING PLANT (continued on next page)

Is building mechanically cooled? [ ]Yes [ ]No

(A) System Type Code ______ (B) Energy Source Code _______ (C) Maintenance Code __________
D. Control Code ________ (E) Voltage Code ___________

(A) System type code
1. Reciprocating chiller
2. Centrifugal chiller
3. Absorption chiller
4. Solar assisted-absorption chiller
5. Evaporative chiller
6. Heat pulmp
7. DX system
8. Screw compressor
9. Window or thru-wall unit
10. Other (define)

(B) Energy source code
1. Electric Motor
2. Combustion engine
3. Steam turbine
4. Steam boiler
5. Purchased steam

(C) Maintenance Code
1. Good
2. Average
3. Fair
4. Poor

(D) Control Code
1. Manual
2. Somewhat Automated
3. Highly Automated

(E) Voltage Code
1. 120/single phase
2. 208-220/single phase
3. 208-220/3-phase
4. 440-480/3-phase

6. COOLING PLANT (continued)

Operation Profile:

____________hrs/weekday _______________hrs/Sat _____________hrs/Sun __________wks/yr

Estimated Annual hours of Operation __________________

From (month) _________________through (month) _________________

Cooling Degree days ________________ (see table on page 15)
Comments:

---

7. DOMESTIC HOT WATER

Domestic Hot Water Heated by:
[ ]Electricity [ ]Natural Gas [ ]Oil [ ]Steam [ ]Heat pump [ ]Other, specify

Number of Units	General Location(s)of Unit(s)	Is there a re-circulation loop?
Daily Usage (if known) ____________gal/day	Hot Water Temp. At point of Use ______________ At heater ______________	
Temp. of city water	Is tank wrapped? [ ]Y [ ]N	Do obstructions prevent wrapping? [ ]Y [ ]N
Distance form Heater to Point of use _________Nearest __________Farthest	Hot Water Uses for Other than Laveratories	

---

8. FOOD PREPARATION AND STORAGE AREA EQUIPMENT

Item	Exists	Total load(if known) KW	Item	Exists	Total load (if known) KW
Ranges	Yes No	___________	Ovens	Yes No	___________
Steam Tables	Yes No	___________	Frying Tables	Yes No	___________
Freezers	Yes No	___________	Refrigerators	Yes No	___________
Walk-in Refer	Yes No	___________	Walk-in Freezer	Yes No	___________
Infra-red warmer	Yes No	___________	Dishwashers	Yes No	___________
Microwaves	Yes No	___________	Hoods w/Exhaust fans	Yes No	___________
Mixers	Yes No	___________	Other, Define _______________	Yes No	___________

9. LIGHTING

Building Area*	Type Code of fixture	Approximate number of fixtures	Average watts per fixture	Operating hours/day	Average footcandles**

Lighting Type Codes

A. Incandescent
B. Flourescent
C. Mercury Vapor
D. High Pressure Sodium
E. Low Pressure Sodium
F. Metal Halide

*Include indoor and outdoor areas.
** Optional

Comments : (e.g., specially installed energy saving fixtures, bulbs, controls such as wall switchers, timeclocks, dimmers, etc.)

10. SOLAR AND RENEWABLE RESOURCE POTENTIAL

Location
[ ]Urban [ ]Suburban [ ]Rural

Building Characteristics
# of Stories ____ General shape* ___________ [ ]Roof Unshaded [ ]Southern Wall Unshaded

Roof Indicate orientation on pg. 6** [ ]Flat [ ]Pitched	Roof's primary structural material**	Type of Roofing**

Composition of Southern Facing Wall	Southern Facing Wall Glass Area [ ]Less than 25% [ ]25-75% [ ]Over 75%

Mean Insolation (Btus/sq.ft.) ***		**Mean Wind Speed (miles/hr)*****	
Jan ______________	Jul ______________	Jan ______________	Jul ______________
Feb ______________	Aug ______________	Feb ______________	Aug ______________
Mar ______________	Sep ______________	Mar ______________	Sep ______________
Apr ______________	Oct ______________	Apr ______________	Oct ______________
May ______________	Nov ______________	May ______________	Nov ______________
Jun ______________	Dec ______________	Jun ______________	Dec ______________

Does the building have adjoining open space along the southern wall? [ ]Yes [ ]No

Monthly Mean Daily Insolation on A Horizontal Surface (Btu/ft2)

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Seattle												
Tacoma	277	513	978	1487	1856	1886	2089	1668	1196	694	384	236
Spokane	439	753	1185	1749	2078	2199	2454	2052	1491	830	483	277

Monthly Mean Wind Speed (miles/hr)

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Seattle	8	8	9	8	8	8	7	7	7	7	7	8
Spokane	8	9	9	9	8	8	8	8	8	8	8	8
Olympia	7	7	8	7	6	6	6	6	5	6	6	8

Source: Climatic Atlas of the United States

Remarks****

*Note building characteristics, indicating shape as square, rectangular, E-shaped, H-shaped, L-shaped.
**Note roof design. For the orientation of a pitched roof, indicate the compass direction of a line perpendicular to the ridgeline in the direction of the down slope. Note presence of roof obstructions such as chimneys, space conditioning equipment, water towers, mechanical rooms and stairwells. Identify the principal structural material of the roof, e.g., steel concrete, or wood structural components. Also identify the type of roofing such as shingle, slate, or built-up.
***Using information from the National Weather Service, the WSU Energy Program, or from charts provided above, enter monthly mean wind speeds and monthly mean daily insolation on a horizontal surface.
****Note any special conditions or characteristics related to potential for solar or other renewable resource application.

11. ENERGY SAVINGS

INSTRUCTIONS: This section is to be completed by the auditor after the walk-through portions of the audit. First, check the boxes which state the range of the percent of energy consumption which would be saved by implementing the operation and maintenance items recommended in section 2 of this book. Second, calculate the range of energy and cost savings by multiplying the estimated percentages by the annual electrical and fuel consumption date on this audit report.

Check two boxes in each category:

Range of Electrical Savings [ ]0% [ ]5% [ ]10% [ ]15% [ ]20% [ ]25% [ ]Other____

Range of Fuel Savings [ ]0% [ ]5% [ ]10% [ ]15% [ ]20% [ ]25% [ ]Other____

Calculate ranges of energy and cost savings:

Range of Electrical Savings

	% Range		Annual Electrical consumption kWh		Range of Electrical savings kWh	% Range		Annual Electrical dollars spent		Range of Electrical Dollar savings
Lower Bound	_______	X	___________	=	________	_____	X	$_________	=	$____________
Upper bound	_______	X	___________	=	________	_____	X	$_________	=	$____________

Range of Fuel Savings

	% Range		Annual fuel consumption Btu		Range of fuel savings Btu	% Range		Annual Fuel dollars spent		Range of Fuel Dollar savings
Lower Bound	_______	X	___________	=	________	_____	X	$_________	=	$____________
Upper bound	_______	X	___________	=	________	_____	X	$_________	=	$____________

The auditor is not responsible if actual savings resulting from the implementation of the energy conservation opportunities listed in this section do not fall between the roughly estimated ranges which are specified.

Total Range of operation and maintenance energy savings (total all fuels):

From _____________ Btu to _______________Btu.
(lower bound) (upper bound)

Comments:

ANNUAL HEATING DEGREE DAY (HDD) AND COOLING DEGREE DAY (CDD) NORMALS FOR ________________STATE BY COUNTY (19__ - ___)

COUNTY	STATION	ANNUAL	
		HDD	CDD

Note: For each site, heating degree day normals are reported in the left column, cooling degree day normals in the right. “Station” refers to the NOAA climatological measuring site from which data are taken to represent the county as a whole. Stations are chosen to be representative of the county according to the location relative to isotherms. Temperature base for heating and cooling degree day is 65º F.

You can find these for your region by contacting local weather service stations or the National Oceanic and Atmospheric Administration.

WSUCEEP2003-038

ENERGY AUDITOR CHECKLIST **

A. BUILDING ENVELOPE	Does this problem exist?		Recommended		N/A
	Y	N	Y	N	
1. Improper alignment and operation of windows and doors allows excessive infiltration.	[ ]	[ ]			
Suggested O & Ms:					
a. Realign or re-hang windows or doors that do not close properly. In extreme cases, consider permanent sealing of windows.			[ ]	[ ]	[ ]
b. Make sure automatic door closing mechanisms work properly.			[ ]	[ ]	[ ]
c. Replace or repair faulty gaskets in garage or on other overhead doors.			[ ]	[ ]	[ ]
Suggested ECMs:					
a. Resize exterior doors; i.e., delivery doors, making them smaller to reduce excessive infiltration.*			[ ]	[ ]	[ ]
b. Add expandable separate enclosures, where practical.			[ ]	[ ]	[ ]
c. Install self-closing doors on openings to unconditioned spaces.			[ ]	[ ]	[ ]
d. Install a switch on overhead doors that prevents activation of heating and cooling units when doors are open.			[ ]	[ ]	[ ]
e. Install vestibule doors at major entrances.*			[ ]	[ ]	[ ]
2. Weather-stripping and caulking around windows, doors, conduits, piping, exterior joints, or other areas of infiltration where it is worn, broken or missing.	[ ]	[ ]			
Suggested O&Ms:					
a. Replace worn and/or broken weather-stripping and caulking.			[ ]	[ ]	[ ]
b. Replace broken or cracked windows. (Air leakage is most evident when wind is blowing against the side of the building.)			[ ]	[ ]	[ ]
Suggested ECMs:					
a. Where practical, cover all windows and through the wall cooling units when not in use. Specially designed covers can be obtained at relatively low cost.			[ ]	[ ]	[ ]
b. In areas with constant strong winds, install wind screens to protect exterior doors from direct blast of prevailing winds. Screens can be opaque, constructed of metal framing with armored glass. Careful positioning is necessary for infiltration control.			[ ]	[ ]	[ ]

Measures marked "" may have an adverse affect on indoor air quality. Implementation of these measures is not required.
**All ECMs listed here are potential energy conservation opportunities.

ENERGY AUDITOR CHECKLIST

A. BUILDING ENVELOPE	Does this problem exist?		Recommended		N/A
	Y	**N**	**Y**	**N**	
3. Doors and /or windows separating conditioned from non-conditioned areas (including outdoors) are left open.	[ ]	[ ]			
Suggested O&Ms:					
a. Post instructions.			[ ]	[ ]	[ ]
b. Assure that automatic door closers function properly.			[ ]	[ ]	[ ]
4. Excessive expanses of glass exist on exterior walls.	[ ]	[ ]			
Suggested O&Ms:					
a. When replacing windows, replace with thermopanes, utilizing the same casings. *			[ ]	[ ]	[ ]
b. Keep curtains and drapes closed in unoccupied spaces.			[ ]	[ ]	[ ]
Suggested ECMs:					
a. Totally or partially insulate non-operable windows. Consider replacing non-operable window with walls.			[ ]	[ ]	[ ]
b. Install double-pane windows.			[ ]	[ ]	[ ]
c. Consider adding reflective or heat absorbing film to minimize solar gain in summer and heat loss in winter. (Note: Any window film reduces natural lighting and winter solar gain.)			[ ]	[ ]	[ ]
d. Install adjustable outdoor shading devices.			[ ]	[ ]	[ ]
e. Attach storm glazing to moveable sash of operable windows.			[ ]	[ ]	[ ]
5. There is no insulation between conditioned and unconditioned spaces.	[ ]	[ ]			
Suggested ECM:					
a. Insulate between heated/cooled spaces and unconditioned or outside areas such as parking garages, porticos, storage, basements and attics.			[ ]	[ ]	[ ]
6. Ceiling/roof insulation is inadequate or has been water damaged.	[ ]	[ ]			
Suggested O&Ms:					
a. Before replacing water damaged insulation, repair roof where required.			[ ]	[ ]	[ ]
b. Verify that vapor barrier faces the conditioned space and is intact.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Add new insulation to meet recommended standard. (check the cost effectiveness of this measure particularly if your facility is over there stories.)			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST

A. BUILDING ENVELOPE	Does this problem exist? Y	N	Recommended Y	N	N/A
7. Blinds and curtains are not used to help insulate the building.	[ ]	[ ]			
Suggested O&Ms: a. Instruct personnel to close interior shading devices to reduce night heat loss in winter and to reduce solar heat gain during the summer.			[ ]	[ ]	[ ]
b. Repair or replace damaged or missing shading devices.			[ ]	[ ]	[ ]
c. Place reminders where appropriate.			[ ]	[ ]	[ ]
Suggested ECMs: a. Add reflective or heat absorbing films to reduce solar heat gain in summer. (Caution: Natural lighting and solar heat gain in winter will be reduced. Also, unless protected by an additional layer of glass, these films are subject to damage.			[ ]	[ ]	[ ]
b. Install outdoor shading devices.			[ ]	[ ]	[ ]

B. BUILDING OCCUPANCY	Does this problem exist? Y	N	Recommended Y	N	N/A
8. Off-hour activities extend operating hours for energy using systems.	[ ]	[ ]			
Suggested O&Ms: a. Reschedule off-hour activities to accommodate partial shutdown of building systems other than ventilation systems.			[ ]	[ ]	[ ]
b. Reschedule custodial and cleaning activities during working hours whenever possible.			[ ]	[ ]	[ ]
c. Re-examine original assumptions regarding occupancy patterns and building usage. Modify patterns for increased energy efficiency.			[ ]	[ ]	[ ]
Suggested ECM: a. Install an automated energy management system that will control all spaces in accordance with usage.			[ ]	[ ]	[ ]
9. Building has extended occupancy areas such as computer rooms.	[ ]	[ ]			
Suggested O&Ms: a. Isolate these spaces (including related support services such as restrooms and break areas) from the portion of the building having fewer operating hours.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST					
C. HVAC -- CONTROLS	**Does this problem exist?**		**Recom-mended**		**N/A**
	Y	**N**	**Y**	**N**	
10. Thermostats on heating/cooling units are vulnerable to occupant adjustment.	[ ]	[ ]			
Suggested O&Ms:					
a. Reset thermostats to correct settings.			[ ]	[ ]	[ ]
b. Install or replace locking screws to prevent tampering.			[ ]	[ ]	[ ]
c. Install tamper-proof locking covers on thermostats.			[ ]	[ ]	[ ]
Suggested ECMs:					
a. Install pre-set solid-state electric thermostats if existing controls are electric.			[ ]	[ ]	[ ]
b. Relocate thermostats in return air ducts where they will be inaccessible to occupants.			[ ]	[ ]	[ ]
11. Space temperatures are higher or lower than thermostat settings.	[ ]	[ ]			
Suggested O&Ms:					
a. Recalibrate thermostat.			[ ]	[ ]	[ ]
b. Blow out moisture, oil and dirt form pneumatic lines (for pneumatic systems); clean contacts if electrical control system.			[ ]	[ ]	[ ]
c. Recalibrate controllers.			[ ]	[ ]	[ ]
d. Ensure that control valves and dampers are modulated properly.			[ ]	[ ]	[ ]
e. Ensure that heat generating device is producing heat and that heat distribution to the space is unobstructed.			[ ]	[ ]	[ ]
f. Make sure that air intake volume is not excessive.			[ ]	[ ]	[ ]
Suggested ECM:					
a. For electric control system, install pre-set solid-state thermostats which do not require calibration.			[ ]	[ ]	[ ]
12. Thermostat settings have not been adjusted for change in seasons.	[ ]	[ ]			
Suggested O&Ms:					
a. Adjusted thermostats to 68ºF in heating season[1] and to 78ºF during cooling season.[2]			[ ]	[ ]	[ ]
b. Change the location of thermostats from areas subject to extreme temperature fluctuations, such as next to window, or over a heating or cooling unit.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Replace existing thermostat with a thermostat which has a separate setting for cooling and a separate setting for heating or use one thermostat to control heating and one thermostat to control cooling.			[ ]	[ ]	[ ]
[1] except for interior zones requiring cooling					
[2] except for reheat systems					

ENERGY AUDITOR CHECKLIST					
C. HVAC -- CONTROLS	**Does this problem exist?**		**Recom-mended**		**N/A**
	Y	**N**	**Y**	**N**	
13. Control devices are not inspected on a regular basis.	[ ]	[ ]			
Suggested O&M:					
a. Routinely check all time clocks and other control equipment for proper operation, correct time and day and for night and proper programming of on-off set points. Protect from unauthorized adjustment.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Use an automated energy management system.			[ ]	[ ]	[ ]
14. Building temperatures are not adjusted for unoccupied periods.	[ ]	[ ]			
Suggested O&Ms:					
a. Reduce thermostat settings by a minimum of 10ºF at nights, for weekends and holidays during heating season, but maintain ventilation..			[ ]	[ ]	[ ]
b. Shut down air conditioning units at night, on weekends and holidays.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Install automatic controls such as time clocks or automated management systems.			[ ]	[ ]	[ ]
15. Unoccupied or little used areas are heated or cooled unnecessarily.	[ ]	[ ]			
Suggested O&Ms:					
a. Reduce winter thermostat settings to 55ºF in unoccupied areas.			[ ]	[ ]	[ ]
b. Where possible, turn off heating systems if nothing ;in space can freeze.			[ ]	[ ]	[ ]
c. Use spot heaters/coolers in large spaces with low occupancy.*			[ ]	[ ]	[ ]
d. Increase summer thermostat setting, in unoccupied areas, if possible.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Install system controls to reduce heating/cooling of unoccupied spaces.			[ ]	[ ]	[ ]
16. Heating/cooling equipment is started before occupants arrive and/or is operating during last hour of occupancy.	[ ]	[ ]			
Suggested O&M:					
a. Experiment with star-up times and duration of operation to determine satisfactory comfort levels for occupants. Reduce or turn off heating and cooling during the last hour of occupancy, allowing the building to "coast."			[ ]	[ ]	[ ]
Suggested ECM:					
a. Install a time clock or an automated energy management system that will reduce heating and /or cooling. Maintain ventilation rates.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST

C. HVAC – VENTILATION	Does this problem exist?		Recom-mended		N/A
	Y	N	Y	N	
17. Air flow to space feels unusually low or is inconsistent form one space to another. Suggested O&Ms: a. Utilize ductwork access openings to check for any obstructions such as loose hanging insulation (in lined ducts), loose turning vanes and accessories, and closed volume and fire dampers. Adjust, repair or replace as necessary. b. Inspect all room air outlets and inlets (diffusers, registers and grilles). They should be kept clean and free of all dirt and obstructions. Clean and remove obstructions as necessary. c. Clean or replace dirty or ineffective filters on a regular basis. d. Post signs instructing occupants not to place objects where they will obstruct air flow. e. Rebalance system.					
18. Large spaces having low occupancy are maintained at comfort conditions. Suggested O&Ms: a. Reduce overall ventilation in space. * b. Consider regrouping activities into smaller areas which can be conditioned separately form remainder of building.					
19. Heating/cooling equipment is operating in lobbies, corridors, vestibules and /or other public areas. Suggested O&Ms: a. Lower heating set points in the above areas if there is no possibility of freeze-up. Disconnect electrical heating units (or switch off at breaker box). Maintain ventilation. b. Close HVAC supply ducts serving the above areas.* Suggested ECM: a. Properly adjust and balance air/water systems and controls.					
20. An excessive quantity of outdoor air is used to ventilate the building. Suggested O&Ms: a. Reduce outdoor air quantity to the minimum allowed by codes by adjusting outdoor air dampers during hours of occupancy. b. Repair any malfunctioning ventilation equipment. Suggested ECM: a. Replace old style dampers with new high quality opposed-blade models with better close-off ratings. b. Repair leaking or failed dampers.					

ENERGY AUDITOR CHECKLIST					
C. HVAC – VENTILATION	**Does this problem exist?**		**Recom-mended**		**N/A**
	Y	**N**	**Y**	**N**	
21. Outdoor air intake dampers open when building is unoccupied.	[ ]	[ ]			
Suggested O&Ms:					
a. Close outdoor air dampers when building is unoccupied. Be sure dampers have proper seals and adjust to ensure complete closure.			[ ]	[ ]	[ ]
b. Where codes permit, close outdoor air dampers during first and last hours of occupancy to permit fast warm-up and cool-down.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Install controls which will automatically close dampers during unoccupied periods.			[ ]	[ ]	[ ]
22. Return, outdoor air and exhaust dampers are not sequencing properly.	[ ]	[ ]			
Suggested O&Ms:					
a. Adjust damper linkage.			[ ]	[ ]	[ ]
b. Be sure damper motors are operating properly.			[ ]	[ ]	[ ]
c. Readjust position indicators to accurately indicate damper positions.			[ ]	[ ]	[ ]
d. Reset linkage, repair or replace dampers if blades do not close tightly.			[ ]	[ ]	[ ]
e. Close all outdoor air intake dampers when equipment is shut off and when building is unoccupied.*			[ ]	[ ]	[ ]
Suggested ECM:					
a. Replace old style dampers with new high quality opposed-blade models with better close-off ratings.			[ ]	[ ]	[ ]
23. Ventilation systems are not utilized for natural cooling capability.	[ ]	[ ]			
Suggested O&M:					
a. Whenever possible, use outside air for cooling rather than using refrigeration. (use economizer cycle, if available.)			[ ]	[ ]	[ ]
Suggested ECM:					
a. Install an economizer cycle with enthalpy control to optimize use of outside air for cooling.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST					
C. HVAC	**Does this problem exist?**		**Recom-mended**		**N/A**
	Y	**N**	**Y**	**N**	
24. Exhaust system operation is not programmed.	[ ]	[ ]			
Suggested O&Ms:					
a. Discontinue use of unnecessary exhaust fans.*			[ ]	[ ]	[ ]
b. Re-wire restrooms' exhaust fans to operate only when lights are on. (Fans are often wired in reverse. Correct as needed.)*			[ ]	[ ]	[ ]
c. Establish schedules so that exhaust fans run only when needed.*			[ ]	[ ]	[ ]
d. Group smoking and other areas with similar exhaust requirements so that they may be served by one exhaust system. Reduce ventilation in remaining non-contaminated areas.*			[ ]	[ ]	[ ]
Suggested ECMs:					
a. Install time clocks or other controls to shutoff exhaust system when not needed (when permitted by code).*			[ ]	[ ]	[ ]
b. Install a rheostat in series with exhaust fan to modulate fan speed so that no more than the necessary amount of air will be exhausted.*			[ ]	[ ]	[ ]
c. Install chemical or electronic odor or particulate remover to reduce the need for using outside air for ventilation.*			[ ]	[ ]	[ ]
d. Install controlled or gravity dampers on all exhaust ducts to close ducts when fan is not operating.*			[ ]	[ ]	[ ]
25. Air filters and heating/cooling coils do not receive scheduled maintenance.	[ ]	[ ]			
Suggested O&Ms:					
a. Develop maintenance schedule.			[ ]	[ ]	[ ]
b. Install filter pressure-drop gauges.			[ ]	[ ]	[ ]
26. Duct or pipe insulation is damaged or missing.	[ ]	[ ]			
Suggested O&Ms:					
a. Repair.			[ ]	[ ]	[ ]
b. Replace.			[ ]	[ ]	[ ]
c. Protect.			[ ]	[ ]	[ ]
27. Fan drive belts deflect excessively. (assure fan motor circuit is locked out before testing.)	[ ]	[ ]			
Suggested O&M:					
a. adjust fan belt tension.			[ ]	[ ]	[ ]
28. Air leaks from ducts and plenums are noticeable.	[ ]	[ ]			
Suggested O&M:					
a. Repair leaks.			[ ]	[ ]	[ ]

<table>
<tr><th colspan="6">ENERGY AUDITOR CHECKLIST</th></tr>
<tr><th rowspan="2">C. HVAC -- HEATING</th><th colspan="2">Does this problem exist?</th><th colspan="2">Recom-mended</th><th rowspan="2">N/A</th></tr>
<tr><th>Y</th><th>N</th><th>Y</th><th>N</th></tr>
<tr><td>29. Air inlets or outlets are dirty or obstructed.

Suggested O&Ms:
a. Clean
b. Remove obstructions.
c. Remove access covers and inspect turning vanes, fire dampers, and splitters.</td><td>[ ]</td><td>[ ]</td><td>[ ]
[ ]
[ ]</td><td>[ ]
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[ ]</td><td>[ ]
[ ]
[ ]</td></tr>
<tr><td>30. boiler combustion efficiency is not tested on a scheduled basis.

Suggested O&Ms:
a. Prepare testing schedule and log of test results.
b. Conduct combustion efficiency tests.</td><td>[ ]</td><td>[ ]</td><td>[ ]
[ ]</td><td>[ ]
[ ]</td><td>[ ]
[ ]</td></tr>
<tr><td>31. Boilers are not maintained on a scheduled basis.

Suggested O&M:
a. Perform maintenance per manufacturer’s instructions.</td><td>[ ]</td><td>[ ]</td><td>[ ]</td><td>[ ]</td><td>[ ]</td></tr>
<tr><td>32. Multiple boilers or heaters fire simultaneously.

Suggested O&M:
a. Adjust controls so that boiler #2 will not fire until boiler #1 can no longer satisfy the demand.

Suggested ECM:
a. Purchase and install automatic staging controls, if applicable.</td><td>[ ]</td><td>[ ]</td><td>[ ]
[ ]</td><td>[ ]
[ ]</td><td>[ ]
[ ]</td></tr>
<tr><td>33. Stack temperature appears excessively high (greater than 400ºF plus room temperature).

Suggested O&Ms:
a. Ensure that proper amount of air for combustion is available in furnace room.
b. Examine and clean air intake filters.
c. Perform flue gas analysis on a regular basis to ensure proper air to fuel ratio.
d. If furnace is over-firing, verify that spuds and nozzles are properly sized. Also check that fuel pressures are not too high.

NOTE: Checks and maintenance of boiler operations should be performed by qualified personnel. If there are none on the staff of the institution, consideration should be given to obtaining assistance from a service contractor.

Suggested ECM:
a. Purchase kit for flue gas analysis if frequent testing is anticipated.</td><td>[ ]</td><td>[ ]</td><td>[ ]
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</table>

ENERGY AUDITOR CHECKLIST

C. HVAC -- HEATING	Does this problem exist? Y	N	Recom-mended Y	N	N/A
34. Water in heating system is heated when there is no need.	[ ]	[ ]			
Suggested O&M:					
a. Turn off boiler, pumps or heat source.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Install control to automatically shut down heat generating device when outside air temperature reaches 60ºF.			[ ]	[ ]	[ ]
35. Condensate from street stream is being discharged to sewer drain.	[ ]	[ ]			
Suggested ECM:					
a. Install pump to return condensate to boiler or return condensate by gravity, if possible. Condensate can also be used to heat domestic water or boiler combustion air prior to its return to the boiler feedwater system.			[ ]	[ ]	[ ]
36. heating pilot lights are on during cooling season.	[ ]	[ ]			
Suggested O&M:					
a. Turn pilots off. (Enter shut-off and turn-on dates in your log book and post a notice in the boiler/furnace room.)			[ ]	[ ]	[ ]
Suggested ECM:					
a. Replace worn units with new electronic ignition models to avoid unnecessary fuel consumption.			[ ]	[ ]	[ ]
37. Steam radiators or other steam equipment fails to heat, or is operating erratically.	[ ]	[ ]			
Suggested O&Ms:					
a. Check the temperature of the pipe on the downstream side of steam traps. If it is excessively hot, the trap probably is passing steam. This can be caused by dirt in the trap, a valve off the stem, excessive steam pressure, or worn trap parts (especially valves and seats). If the pipe is moderately hot (as hot as a hot water pipe), it probably is passing condensate, which it should do. If it's cold, the trap is not working at all, and should be replaced or repaired. Initiate a steam trap maintenance program.			[ ]	[ ]	[ ]
b. Clean or replace thermostatic control valves on radiators.			[ ]	[ ]	[ ]
c. Check air vent valve. If not operating properly, replace.			[ ]	[ ]	[ ]
d. If thermostatic trap is malfunctioning, clean or replace bellows element.			[ ]	[ ]	[ ]
e. Water pockets may be obstructing steam flow. Correct by re-pitching or rerouting pipes.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST

C. HVAC -- HEATING	Does this problem exist? Y	N	Recom-mended Y	N	N/A
38. Steam, condensate and heating water piping insulation is in disrepair or missing.	[ ]	[ ]			
Suggested O&M:					
a. Inspect pipes for broken or missing insulation. Repair or replace as needed.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Install additional pipe insulation in accordance with design specifications and energy conservation codes.			[ ]	[ ]	[ ]
39. Operation of oil burner is accompanied by excessive smoke and sooting.	[ ]	[ ]			
Suggested O&Ms:					
a. Inspect burner nozzles for wear, dirt and incorrect spray angles. Clean and adjust as necessary.			[ ]	[ ]	[ ]
b. Verify that oil is flowing freely and that oil pressure is correct.			[ ]	[ ]	[ ]
c. Perform flue gas analysis to set proper air to fuel ratio.			[ ]	[ ]	[ ]
d. If burning heavy oil, check oil temperature.			[ ]	[ ]	[ ]
e. If steam atomizing burners, check steam-oil differential pressure.			[ ]	[ ]	[ ]
Suggested ECMs:					
a. Purchase kit for flue gas analysis if frequent testing is anticipated.			[ ]	[ ]	[ ]
b. Purchase new burner nozzles or tips.			[ ]	[ ]	[ ]
40. Soot and odors are detected in areas where they are not expected.	[ ]	[ ]			
Suggested O&Ms:					
a. Heat exchanger may have burned out. Replace.			[ ]	[ ]	[ ]
b. Stack draft may be inadequate. Clean and correct as necessary.			[ ]	[ ]	[ ]
c. Perform flue gas analysis to obtain proper air to fuel ration.			[ ]	[ ]	[ ]
d. Check operation of furnace draft controller.			[ ]	[ ]	[ ]
e. Check boiler setting for leaks.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Purchase kit for flue gas analysis if frequent testing is anticipated.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST					
C. HVAC -- HEATING	**Does this problem exist?**		**Recom-mended**		**N/A**
	Y	**N**	**Y**	**N**	
41. Evidence indicated faulty or inefficient boilers or furnaces.	[ ]	[ ]			
Suggested O&Ms:					
a. Remove scale deposits, accumulation of sediment and boiler compounds on water side surfaces. Examine and treat rear portion of boiler (the area most susceptible to scale formation).			[ ]	[ ]	[ ]
b. Remove soot from tubes.			[ ]	[ ]	[ ]
c. Observe the fire when the unit shuts down. If the fire does not cut off immediately, it could indicate a faulty solenoid valve. Repair or replace as necessary.			[ ]	[ ]	[ ]
d. Inspect all boiler insulation, refractory, brick work and boiler casing for hot spots and air leaks. Repair and seal as necessary.			[ ]	[ ]	[ ]
Suggested ECMs:					
a. Replace dangerous or ineffective units with more efficient modular type units. (Note: Do not install oversize unit.)			[ ]	[ ]	[ ]
b. If applicable, install baffle-type devices in the tubes to improve efficiency.			[ ]	[ ]	[ ]
42. Air is humidified.	[ ]	[ ]			
Suggested O&M:					
a. Discontinue or reduce humidification where possible.			[ ]	[ ]	[ ]
43. Burner short-cycles.	[ ]	[ ]			
Suggested O&Ms:					
a. Start-stop limit switches may be set too closely. Reset as required.			[ ]	[ ]	[ ]
b. Thermostat may be faulty. Replace if necessary.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Employ control specialist to adjust control.			[ ]	[ ]	[ ]
44. Combustion air to boiler/furnace is not preheated.	[ ]	[ ]			
Suggested ECMs:					
a. Utilize heat from flue gas to preheat combustion air by means of a heat recovery device.			[ ]	[ ]	[ ]
b. Consider economizer to transfer heat form flue gas to feed water.			[ ]	[ ]	[ ]
c. Consider heat recovery from continuous blowdown.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST

C. HVAC -- HEATING	Does this problem exist? Y	N	Recom-mended Y	N	N/A
45. Hot water radiation units fail to operate.	[ ]	[ ]			
Suggested O&Ms:					
a. Radiators are air-locked. Open air vents and bleed off air until water appears.			[ ]	[ ]	[ ]
b. Bleed off water in pneumatic air lines if necessary. (Pneumatic lines may be frozen.) Check for air leaks.			[ ]	[ ]	[ ]
c. Repair or replace faulty thermostats.			[ ]	[ ]	[ ]
d. Hot water pump or booster pump may not be functioning. Repair or replace as necessary.			[ ]	[ ]	[ ]
46. Radiators, convectors, baseboards and finned-tube heaters are not providing sufficient heat.	[ ]	[ ]			
Suggested O&Ms:					
a. Boiler temperature may have dropped. Correct as necessary.			[ ]	[ ]	[ ]
b. Bleed air from units.			[ ]	[ ]	[ ]
c. Establish a systematic cleaning schedule.			[ ]	[ ]	[ ]
d. Remove items obstructing discharge grilles.			[ ]	[ ]	[ ]
e. Bleed off water in pneumatic air lines if necessary. (Pneumatic lines may be frozen.) Check for air leaks.			[ ]	[ ]	[ ]
f. Repair faulty valves.			[ ]	[ ]	[ ]
g. Repair or replace faulty thermostats.			[ ]	[ ]	[ ]
h. Hot water pump or booster pump may not be functioning. Repair or replace as necessary.			[ ]	[ ]	[ ]
47. Condensers and cooling towers are not maintained on a scheduled basis.	[ ]	[ ]			
Suggested O&Ms:					
a. Prepare maintenance schedule. Perform maintenance per manufacturer's recommendations.			[ ]	[ ]	[ ]
b. Maintain cooling tower water.			[ ]	[ ]	[ ]
48. Circulating pump operation is manually controlled.	[ ]	[ ]			
Suggested O&M:					
a. Develop operating schedule.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST					
C. HVAC -- COOLING	**Does this problem exist?**		**Recom-mended**		**N/A**
	Y	**N**	**Y**	**N**	
49. Multiple air conditioning compressors start simultaneously.	[ ]	[ ]			
Suggested O&M: a. Adjust controls to stage compressors.			[ ]	[ ]	[ ]
Suggested ECM: a. Should automatic controls not exist, purchase and install. This will allow compressor #2 to cut in when compressor #1 can no longer satisfy space conditioning load.			[ ]	[ ]	[ ]
50. Chiller evaporating and condensing temperatures are not optimized.	[ ]	[ ]			
Suggested O&Ms: a. Increase chiller evaporator temperature following manufacturer's recommendations.			[ ]	[ ]	[ ]
b. Decrease chiller condensing temperature following manufacturer's recommendations.			[ ]	[ ]	[ ]
51. Chiller is operating during cold weather to provide air conditioning.	[ ]	[ ]			
Suggest ECMs: a. Provide a water temperature system injecting cooling tower condenser water directly into the system's chilled water circuits. Except for pumping and cooling tower fan horsepower, this provides free cooling. Special care must be taken in treating and filtering condenser water.			[ ]	[ ]	[ ]
b. If system is forced air, using DX coils and air cooled condenser, install economizer cycle to obtain free cooling.			[ ]	[ ]	[ ]
52. Reheat coils are used to maintain zone temperatures.	[ ]	[ ]			
Suggested ECM: a. Convert to variable air volume system if the reheat coils are not necessary to supply heat during the heating season.*			[ ]	[ ]	[ ]
53. Building utilizes a dual duct or multizone system.	[ ]	[ ]			
Suggested ECMs: a. Convert dual duct or multizone systems to variable air volume, if building has a separate heating season.*			[ ]	[ ]	[ ]
b. Install controls to automatically reset hot and cold deck temperatures.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST

C. HVAC -- COOLING	Does this problem exist? Y	N	Recom-mended Y	N	N/A
54. Air conditioning load trips circuit breaker on extremely warm days.	[ ]	[ ]			
Suggested O&Ms:					
a. Tighten wire lugs if loose.			[ ]	[ ]	[ ]
b. Replace defective circuit breakers.			[ ]	[ ]	[ ]
c. Clean condenser on air cooled systems.			[ ]	[ ]	[ ]
d. Clean Scale build-up in condenser on water cooled systems.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Consider installing insulated underground storage tank that would allow night operation of chiller when electrical demand is low. This reservoir tank would be a source of supply of chilled water for daytime operation. Chiller would not be operated during the day.			[ ]	[ ]	[ ]
55. air of inadequate volume or temperature is being discharged through grilles.	[ ]	[ ]			
Suggested O&Ms:					
a. Defrost evaporator coil if iced. Determine cause of icing and correct.			[ ]	[ ]	[ ]
b. Clean evaporator coil, fins and tubes.			[ ]	[ ]	[ ]
c. Clean or replace air filters.			[ ]	[ ]	[ ]
d. Fire damper may be closed. Open and replace fusible link if necessary.			[ ]	[ ]	[ ]
e. Balancing damper may have slipped and closed. Open to correct position and tighten wing nut.			[ ]	[ ]	[ ]
f. If fan is rotating backwards, reverse rotation by reversing electrical contacts.			[ ]	[ ]	[ ]
g. Clean condenser coil and /or water tower nozzles.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Install differential pressure-sensing switches to alarm when air flow drops significantly.			[ ]	[ ]	[ ]
56. Refrigeration condensers or coils are dirty, clogged and/or not functioning efficiently.	[ ]	[ ]			
Suggested O&Ms:					
a. Determine if normal operating temperatures and pressures have been identified and if all gauges are checked frequently to ensure design conditions are being met.			[ ]	[ ]	[ ]
b. Increased system pressure may be due to dirty condensers which will decrease system efficiency. High discharge temperatures often are caused by defective or broken compressor valves. Repair or adjust as required.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST					
C. HVAC -- COOLING	**Does this problem exist?**		**Recom-mended**		**N/A**
56…	**Y**	**N**	**Y**	**N**	
c. Inspect the liquid line leaving the strainer. If it feels cooler than the liquid line entering the strainer, it is clogged. It is very badly clogged if frost or sweat is visible at the strainer outlet. Clean as required.			[ ]	[ ]	[ ]
d. Clean coils and /or other elements as needed on a scheduled basis. Include dehumidification coils.			[ ]	[ ]	[ ]
57. Chilled water piping, valves and fittings are leaking.	[ ]	[ ]			
Suggested O&Ms:					
a. Repair joint or piping leaks.			[ ]	[ ]	[ ]
b. Repair or replace valves.			[ ]	[ ]	[ ]
58. chiller operation is not optimized. (Listen for short-cycling.)	[ ]	[ ]			
suggested O&Ms:					
a. Raise chilled water supply temperature. (NOTE: This is especially important if system was designed for a 75ºF space temperature and the space setting has been raised to 78ºF for energy conservation purposes.)			[ ]	[ ]	[ ]
b. Remove scale deposits from condensers.			[ ]	[ ]	[ ]
c. Check refrigerant charge.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Reduce peak loads with electric load limiters. (this option saves money but not energy.)			[ ]	[ ]	[ ]
59. Refrigeration compressor short-cycles.	[ ]	[ ]			
Suggested O&Ms:					
a. Refrigerant charge is low or refrigerant is leaking. Find and repair leak. Recharge system.			[ ]	[ ]	[ ]
b. Repair electrical control circuit if required.			[ ]	[ ]	[ ]
c. Reset high/low pressure control differential settings if needed.			[ ]	[ ]	[ ]
d. Evaporation coil may be iced up or dirty. Defrost and clean.			[ ]	[ ]	[ ]
e. Liquid line solenoid valve may be leaking. Repair or replace.			[ ]	[ ]	[ ]
f. If frost is detected on the liquid line strainer, it is clogged. Clean strainer.			[ ]	[ ]	[ ]
g. Clean condenser coil.			[ ]	[ ]	[ ]
h. If condenser is a cooling tower, ascertain if spray nozzles are plugged. Make sure water flow is unobstructed. Clean towers of leaves and debris.			[ ]	[ ]	[ ]
i. Remove scale deposits form shell/tubes on water condensers.			[ ]	[ ]	[ ]
j. Repair suction valves in compressor, if needed.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST					
C. HVAC -- COOLING	**Does this problem exist?**		**Recom-mended**		**N/A**
	Y	**N**	**Y**	**N**	
60. Multiple parallel chillers have no isolation schedule for extended light-load operation.	[ ]	[ ]			
Suggested O&Ms:					
a. Develop load vs. capacity matrix.			[ ]	[ ]	[ ]
b. Isolate unneeded chillers.			[ ]	[ ]	[ ]
61. Steam, hot or chilled water leaks are evident.	[ ]	[ ]			
Suggested O&M:					
a. Repair leaks			[ ]	[ ]	[ ]
62. Steam, hot or chilled water valves do not shut off tight.	[ ]	[ ]			
Suggested O&M:					
a. Repair or replace valve.			[ ]	[ ]	[ ]
63. Conditioned air or heated water is discarded.	[ ]	[ ]			
Suggested ECM:					
a. It is important for building owner to be aware of heat recovery; measures. However, it is not wise to install such equipment without first analyzing the energy characteristics of the building, performance of the hardware, and how it fits into the overall energy plan.			[ ]	[ ]	[ ]
D. DOMESTIC HOT WATER					
64. Hot water temperature is excessive.	[ ]	[ ]			
Suggested O&M:					
a. Lower thermostat or controller set point to 105ºF to 115ºF for general purposes. Consult appropriate codes and regulations for permissible water temperatures for sanitation, health and medical purposes.			[ ]	[ ]	[ ]
65. System insulation is damaged or missing.	[ ]	[ ]			
Suggested O&M:					
a. Repair, replace. Protect as necessary to prevent recurrence of damage.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST					
D. DOMESTIC HOT WATER	**Does this problem exist?**		**Recom-mended**		**N/A**
	Y	**N**	**Y**	**N**	
66. Water temperatures are not reduced during unoccupied periods.	[ ]	[ ]			
Suggested O&M: a. Schedule setbacks (either manually or with existing time clock). Consider schedule's impact on electrical demand.			[ ]	[ ]	[ ]
Suggested ECM: a. Install and appropriate automatic control device.			[ ]	[ ]	[ ]
67. Water leaks are evident.	[ ]	[ ]			
Suggested O&M: a. Repair leaks and defective faucets.			[ ]	[ ]	[ ]
68. Heat pump water heater coils are not maintained on scheduled basis.	[ ]	[ ]			
Suggested O&M: a. Schedule maintenance following manufacturer's recommendations.			[ ]	[ ]	[ ]
69. Hot water recirculating pumps run continuously.	[ ]	[ ]			
Suggested O&M: a. Develop operating schedule to match occupancy.			[ ]	[ ]	[ ]
70. Drips or leaks are evident in hot water systems.	[ ]	[ ]			
Suggested O&M: a. Repair all leaks including those of the faucets and pumps.			[ ]	[ ]	[ ]
71. Electric water heater has no time restrictions on heating cycle.	[ ]	[ ]			
Suggested O&M: a. Utilize "vacation cycle" on water heater when not needed during extended periods. (Note: Complete deactivation could cause leaks.)			[ ]	[ ]	[ ]
Suggested ECM: a. Limit the duty cycle with a time clock or other control devices to avoid adding the water heating load to the building during peak electrical demand periods. (additional hot water storage capacity may be required.)			[ ]	[ ]	[ ]
72. Devices to conserve heated water have not been utilized where practical.	[ ]	[ ]			
Suggested ECMs: a. Install mixing valves.			[ ]	[ ]	[ ]
b. Replace standard faucets with self-closing, flow restrictor valves. (Note: Highly mineralized water or water containing sediment can cause blockages.)			[ ]	[ ]	[ ]
c. Install a solar water heater to assist in meeting building hot water demand. This will reduce significantly consumption of traditional energy fuels in facilities which are large users of hot water.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST					
	Does this problem exist?		Recom-mended		N/A
D. DOMESTIC HOT WATER	Y	N	Y	N	
73. Storage tanks, piping and water heaters are utilized inefficiently.	[ ]	[ ]			
Suggested ECMs:					
a. Install a small domestic hot water heater to maintain desired temperature in water storage tank. This could eliminate the need for operating one of the large space heating boilers during summer months.			[ ]	[ ]	[ ]
b. Install de-centralized water heating.			[ ]	[ ]	[ ]
E. LIGHTING					
74. Incandescent lamps are used in offices, workrooms, hallways, and gymnasiums.	[ ]	[ ]			
Suggested O&Ms:					
a. Where possible use a single incandescent lamp of high wattage rather than two or more smaller lamps of combined wattage.			[ ]	[ ]	[ ]
b. Discontinue using extended service lamps except in special cases such as recessed directional lights where short lamp life is a problem.			[ ]	[ ]	[ ]
c. Discontinue using multi-level lamps. The efficiency of a single wattage lamp is higher per watt than a multi-level lamp.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Replace non-decorative incandescent lamps with more energy conserving types such as fluorescents in general purpose areas and HIDs in large group areas.			[ ]	[ ]	[ ]
75. Lamps and fixtures are not clean.	[ ]	[ ]			
Suggested O&Ms:					
a. Establish a regular inspection and cleaning schedule for lamps and luminaires (fixtures). Dust buildup reduces effectiveness.			[ ]	[ ]	[ ]
b. Replace lens shielding that has turned yellow or hazy with new acrylic lenses which do not discolor.			[ ]	[ ]	[ ]
c. Replace outdated or damaged luminaires with modern typed that are easy to clean.			[ ]	[ ]	[ ]
76. Lamps are replaced individually as they burn out.	[ ]	[ ]			
Suggested O&M:					
a. Establish a group relamping schedule. Lamp manufacturer's sales offices can provide a computerized relamping schedule at minimal or no cost.			[ ]	[ ]	[ ]
77. Ceilings and other room surfaces have reduced reflectivity due to dirt.	[ ]	[ ]			
Suggested O&Ms:					
a. Clean surfaces.			[ ]	[ ]	[ ]
b. When repainting or recovering, use coatings or coverings with good reflectance.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST

E. LIGHTING	Does this problem exist? Y	Does this problem exist? N	Recom-mended Y	Recom-mended N	N/A
78. Daylight is not used effectively.	[ ]	[ ]			
Suggested O&Ms:					
a. Locate work stations requiring high illumination adjacent to windows.			[ ]	[ ]	[ ]
b. Switch off lights when daylight is sufficient.			[ ]	[ ]	[ ]
c. Clean windows and skylights.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Install light sensors and dimming equipment which automatically compensate for varying natural lighting conditions.			[ ]	[ ]	[ ]
79. Decorative lighting is excessive and/or not controlled optimally.	[ ]	[ ]			
Suggested O&Ms:					
a. Replace burned out lamp with lower wattage lamps.			[ ]	[ ]	[ ]
b. Establish schedule for manual control or control operation with existing photoelectric or time clock controls if practical.			[ ]	[ ]	[ ]
80. In fixtures where fluorescent lamps have been removed, the ballasts have not been disconnected.	[ ]	[ ]			
Suggested O&M:					
a. Disconnect ballasts, which still use significant amount of energy even though tubes have been removed.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Replace unnecessary tubes with "dummy" types which draw little current and yet provide uniform lighting effect.			[ ]	[ ]	[ ]
81. When burned out fluorescent lamps and/or ballasts have been replace, more efficiently lights have not been installed.	[ ]	[ ]			
Suggested O&Ms:					
a. When relamping, replace fluorescent tubes with more efficient and lower wattage types such as 35-watt instead of 40-watt to achieve a reduction in electrical energy consumption. Wherever possible, replace burned out ballasts with more efficient, lower wattage, energy conserving ballasts.			[ ]	[ ]	[ ]
b. Consider not replacing burned out bulbs or lamps, and disconnecting ballasts in areas where delamping is possible. For example, in four-lamp fixtures allow two lamps to remain, disconnecting appropriate ballasts.			[ ]	[ ]	[ ]
Suggested ECMs:					
a. Install more efficiently fluorescent tubes and ballasts in all existing luminaires (fixtures). (NOTE: Verify that new lamps will work with existing ballasts.)			[ ]	[ ]	[ ]
b. Lowering luminaires (fixtures) will increase illumination levels on the task area, and may permit a reduction in the number of fixtures or the wattage of lamps.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST					
E. LIGHTING	**Does this problem exist?**		**Recom-mended**		**N/A**
	Y	**N**	**Y**	**N**	
82. Lighting is on in unoccupied areas.	[ ]	[ ]			
Suggested O&Ms:					
a. Post instruction to turn off lights when leaving area.			[ ]	[ ]	[ ]
b. Identify areas being controlled by ganged switches.			[ ]	[ ]	[ ]
c. Assure wall switch timers function properly.			[ ]	[ ]	[ ]
Suggested ECMs:					
a. Rewire switches so that one switch does not control all fixtures in multiple work spaces.			[ ]	[ ]	[ ]
b. Provide timer switches in remote or seldom used areas where there will be brief occupancy periods.			[ ]	[ ]	[ ]
83. Security/outdoor lighting is not automatically controlled and /or lighting levels are excessive.	[ ]	[ ]			
Suggested O&Ms:					
a. Replace burned out lamps with lower wattage lamps.			[ ]	[ ]	[ ]
b. Establish manual operation schedule considering change in daylight with season.			[ ]	[ ]	[ ]
c. Control lighting with existing photoelectric or time-clock controls if practical.			[ ]	[ ]	[ ]
d. Eliminate outdoor lighting where practical.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Replace exterior incandescent lamps with more efficient types such as HPS or MH.			[ ]	[ ]	[ ]
84. Deep baffled downlighting fixtures have conventional "R" reflector lamps installed.	[ ]	[ ]			
Suggested O&M:					
a. Replace burned out "R" lamps with elliptical reflector "ER" lamps which yield approximately the same average light level for half the energy cost.			[ ]	[ ]	[ ]
85. Two lamps have not been removed form four-lamp fixtures where possible.	[ ]	[ ]			
Suggested O&M:					
a. Remove two lamps and disconnect ballasts.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST					
F. POWER	**Does this problem exist?**		**Recom-mended**		**N/A**
	Y	**N**	**Y**	**N**	
86. Transformers remain energized when serving no load for extended periods.	[ ]	[ ]			
Suggested O&M: a. Disconnect transformer.			[ ]	[ ]	[ ]
87. Transformer ambient temperature is high.	[ ]	[ ]			
Suggested O&M: a. Assure that a forced ventilation system serving space is functioning or that natural ventilation system openings are not obstructed.			[ ]	[ ]	[ ]
88. Vending machines remain energized during unoccupied periods.	[ ]	[ ]			
Suggested O&M: a. Provide manual operation schedule or connect to existing time clock if practical. Consult with vending company prior to implementation.			[ ]	[ ]	[ ]
89. Refrigerator drinking fountains or recirculating chilled drinking water systems are not controlled for occupancy.	[ ]	[ ]			
Suggested O&M: a. Develop schedule for manual control or connect to existing time clocks or programmable controllers, if practical.			[ ]	[ ]	[ ]
90. Elevator operation is not optimized for occupancy variations.	[ ]	[ ]			
Suggested O&M: a. Consult with manufacturer for possible operating changes.			[ ]	[ ]	[ ]
91. Lubricants used on major rotating equipment with high load factors have not been optimized for reduction of friction losses.	[ ]	[ ]			
Suggested O&M: a. consult with equipment manufacturers and lubricant manufacturers to determine if lubricant change is cost-effective.			[ ]	[ ]	[ ]
92. Substantial electricity demand charges are incurred.	[ ]	[ ]			
Suggested O&M: a. Determine if use of major electrical equipment can be scheduled to reduce demand.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST					
F. POWER	**Does this problem exist?**		**Recom-mended**		**N/A**
	Y	**N**	**Y**	**N**	
93. No records of maintenance for motors and motor driven equipment are available.	[ ]	[ ]			
Suggested O&Ms:					
a. Using name plate data, prepare an up-to-date list of all motors and pumps used in the facility and list routing maintenance to be performed on each. Check regularly for: 1. Correct motor voltage and amperage. 2. Loose connections and worn contacts. 3. Unbalanced voltages on 3-phase motors. 4. Improper grounding. 5. Packing wear. 6. Wear and binding on bearings and drive belts. 7. Proper sequencing of pumps and motors.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Replace worn equipment with more efficient units, if available.			[ ]	[ ]	[ ]
G. REFRIGERATION					
94. Evaporator coils have heavy ice build-up.	[ ]	[ ]			
Suggested O&Ms:					
a. Defrost coils regularly.			[ ]	[ ]	[ ]
b. Determine if automatic defrost system is improperly adjusted or defective.			[ ]	[ ]	[ ]
c. Determine if air is leaking into refrigerated area from defective door gaskets or poorly sealed wiring or piping penetrations.			[ ]	[ ]	[ ]
95. Evaporator temperature is lower than required for produce or process.	[ ]	[ ]			
Suggested O&M:					
a. Increase temperature set-point.			[ ]	[ ]	[ ]
96. System insulation is damaged or missing.	[ ]	[ ]			
Suggested O&M:					
a. Repair or replace. Protect vulnerable sections form future damage. (Do not insulate hot gas piping unless required for safety.)			[ ]	[ ]	[ ]
97. Condensing temperature is excessive.	[ ]	[ ]			
Suggested O&Ms:					
a. Reset following manufacturer's recommendations.			[ ]	[ ]	[ ]
b. Clean condensing fins or tubes.			[ ]	[ ]	[ ]
c. Assure that ventilation for compressor rooms is adequate.			[ ]	[ ]	[ ]
98. Ice-makers are not turned off during extended unoccupied periods.	[ ]	[ ]			
Suggested O&M:					
a. Develop schedule for manual operation.			[ ]	[ ]	[ ]

ENERGY AUDITOR CHECKLIST

H. ANCILLARY SYSTEMS	Does this problem exist?		Recom-mended		N/A
	Y	N	Y	N	
99. Kitchen equipment is not used efficiently.	[ ]	[ ]			
Suggested O&Ms:					
a. Cook with lids in place on pots and kettles.			[ ]	[ ]	[ ]
b. Preheat ovens only for baked goods.			[ ]	[ ]	[ ]
c. Reduce temperature or turn off frying tables and coffee urns during off peak periods.			[ ]	[ ]	[ ]
d. Provide ovens and fryers with loads all of the time they are heated and on.			[ ]	[ ]	[ ]
e. Use dishwasher for full loads only.			[ ]	[ ]	[ ]
f. Shut down exhaust hood fans when not required.			[ ]	[ ]	[ ]
g. Use microwave ovens for small orders.			[ ]	[ ]	[ ]
100. In-house laundry equipment is not used efficiently.	[ ]	[ ]			
Suggested O&Ms:					
a. Develop concise operating procedures for each piece of equipment.			[ ]	[ ]	[ ]
b. Iron only items which require it.			[ ]	[ ]	[ ]
c. Wash and dry full loads only.			[ ]	[ ]	[ ]
d. Consider rescheduling laundry work hours to avoid periods when building experiences its peak electrical load if electricity demand charges are significant.			[ ]	[ ]	[ ]
e. Consider cold water detergents.			[ ]	[ ]	[ ]
101. Swimming pool water temperature is too high.	[ ]	[ ]			
Suggested O&Ms:					
a. Reduce water temperatures to 80º-84ºF if users can accept it.			[ ]	[ ]	[ ]
b. Indoor pool: turn off heater and circulating pumps during periods of non-use.			[ ]	[ ]	[ ]
102. Use of equipment associated with laundry and custodial services coincides with heavy electrical demand periods.	[ ]	[ ]			
Suggested O&M:					
a. Require that major electrical equipment be used in accordance with guidelines that avoid peak electrical demand periods.			[ ]	[ ]	[ ]
Suggested ECM:					
a. Install a demand control system to automatically monitor power demand and to shut off assigned secondary loads to lower demand peaks to pre-established level.			[ ]	[ ]	[ ]

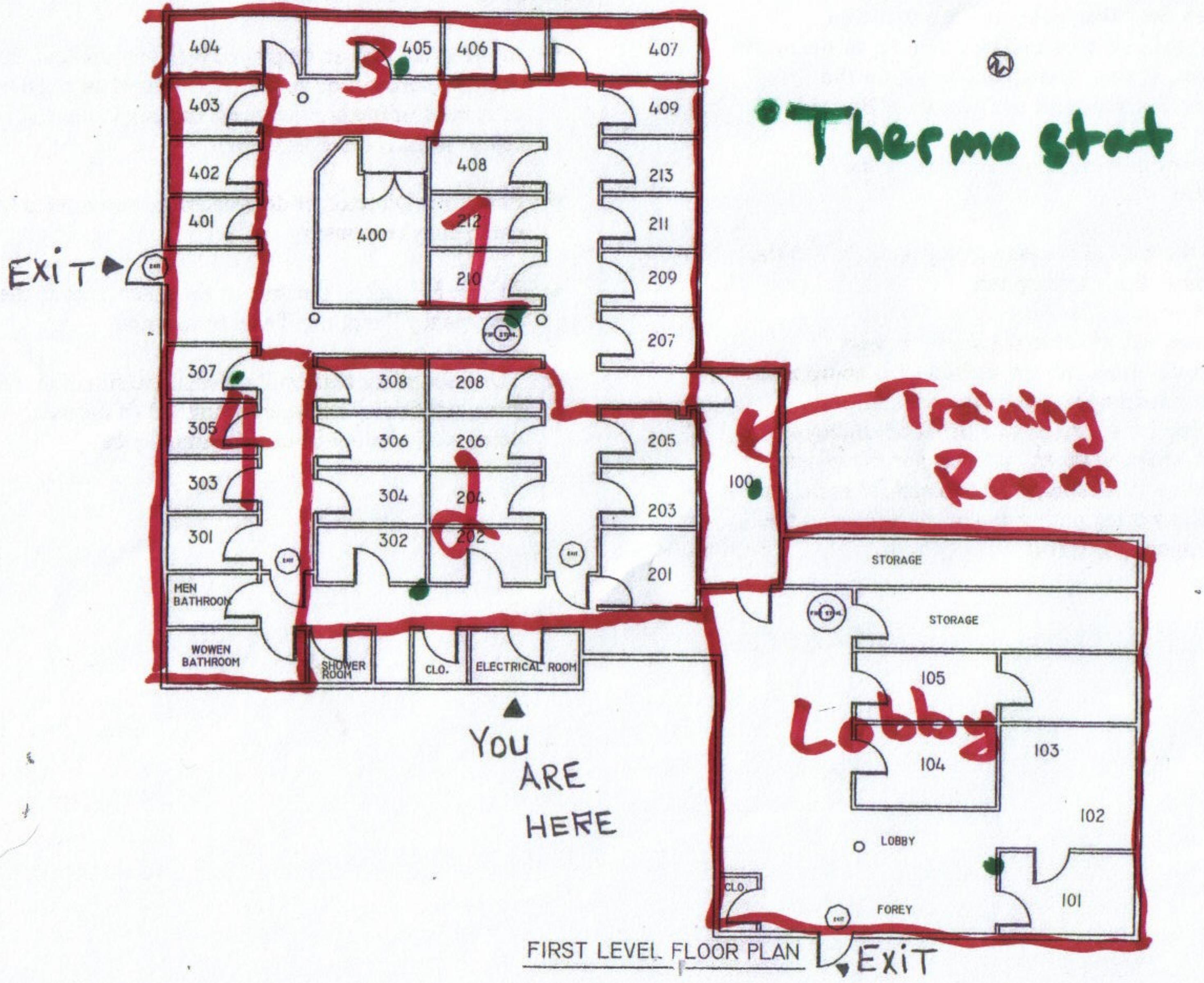
Appendix: B

HVAC

Zone Chart

Calculations

HVAC Runtime Graphs



FIRST LEVEL FLOOR PLAN

NEIT

GENERAL NOTES

PROJECT
ANNIE

BY:
ANNIE DE LOS SANTOS-DIAZ

DRAWING
FIRST LEVEL FLOOR PLAN

REVISIONS	DATE	BY:

SCALE 1/4" = 1'-0"
DATE 01/22/03
SHEET NO. 1 OF

A-1.1

Evaluating HVAC Controllers

The first enhancement to our level-1 energy audit focused on evaluating how effectively the HVAC systems were being controlled and coordinated by the thermostats in the building. We did this by placing our remote temperature recorders into the ducts of each of the 6 HVAC units to record the temperature once every minute for 8 consecutive days. This data was compiled on a spreadsheet for a graphical comparison of the temperatures.

When the HVAC units were off or on a fan-only setting, the average temperature in each of the ducts was roughly 61 ^{o}F. When the units began heating, the temperature in the ducts sharply rose as high as 110 ^{o}F. In order to turn this temperature data into an estimate for fuel consumption, we developed an algorithm to process all 76,206 temperature recordings that would assign an energy consumption value to the given temperature.

There were 3 primary boundary conditions that were used to develop this equation. One boundary condition was that at the minimum recorded temperature in a given duct, the unit was consuming zero fuel. The second boundary condition was that at the maximum temperature in a given duct, the unit was consuming its maximum rated fuel consumption (for the rooftop units, 118,000 BTUs per hour). The third boundary condition was that the output of the total fuel consumption over the 8-day testing period would be roughly 25% of the total fuel consumption of the same month in the previous year.

For the mathematical structure of the equation in question, we decided to use a 2nd-order polynomial in the format a=C*(x-(xmin))^2, where “a” is the fuel consumption of the unit in question, “C” is a constant that helps the equation satisfy the three boundary conditions, and “(x-(xmin))” is equal to a single temperature entry for one duct (x) minus the lowest recorded temperature in that duct (xmin).

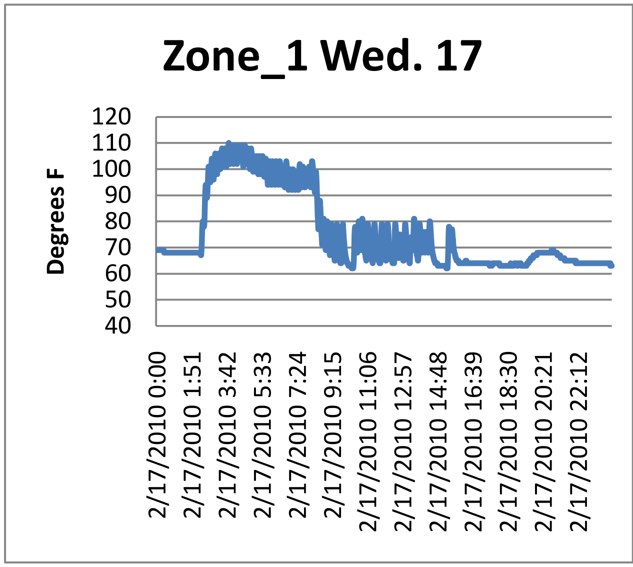
We used a quadratic function instead of a simpler linear function to reduce the “weight” of lower temperature numbers with respect to fuel consumption. For instance, the minimum temperature in one duct was 61 ^{o}F, and the maximum was 111 ^{o}F. We saw that the temperature inside the ducts tended to fluctuate by ~3-5 deg. F even when the machine was not running; this could happen for various reasons, including the heating operation of a different unit. In a linear approximation with 61 deg. equal to zero energy consumption, the energy consumption at 62 would be calculated at roughly 40 BTUs per minute, and the energy consumption at 63 degrees would be calculated at roughly 80 BTUs per minute.

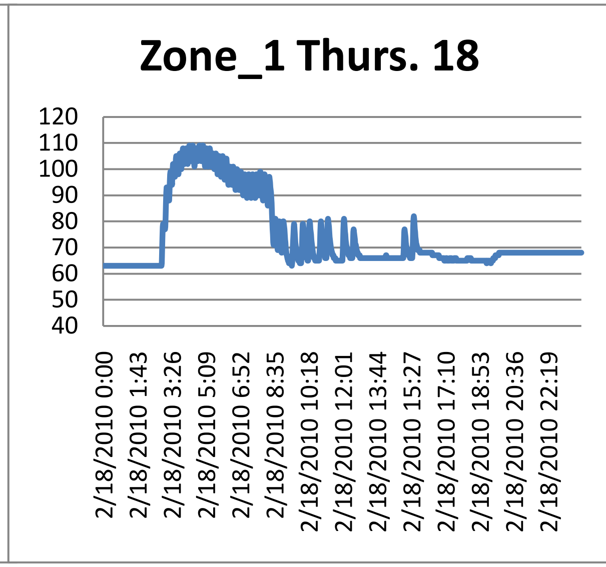
These are relatively high consumption values for temperatures that do not inherently indicate when the machines are running. By using a quadratic we reduced the values at the lower end significantly so that temperatures that clearly indicated a running HVAC unit would compose more of the energy use than temperatures that could fluctuate based on other factors. With a quadratic function, the energy consumption at 62 deg. is calculated at .8 BTUs per minute instead of 40. We found that this reduced the potential for inflated fuel consumption values and made our algorithm more accurate than a linear approximation especially considering the large number of data entries.

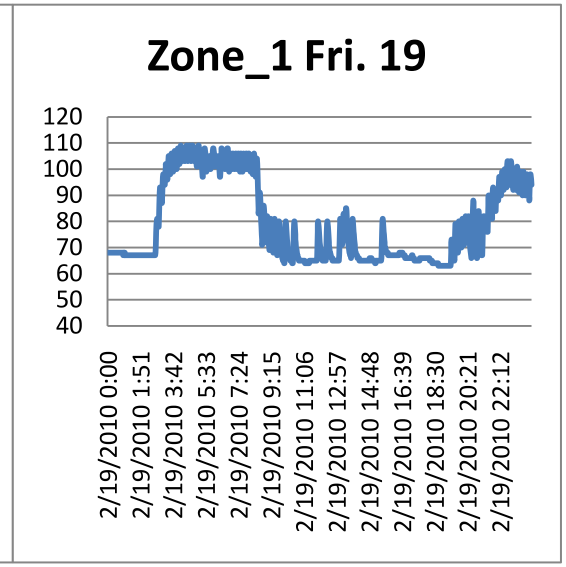
It is important to note here that we only processed cost-of-running estimates for the four rooftop units. The other two units were not included in the analysis for two reasons. The reason the training room heating unit was not included was because it is electric. We found it difficult to develop boundary conditions for the electric heater to match the consistency of the ones for the gas system because the electric bills comprise more than just that heating unit. The gas bills are solely from the gas HVAC units, so we can assume that any estimates of consumption would need to match the known total consumption; matching estimated HVAC unit consumption to total HVAC consumption in the electric bill was not possible.

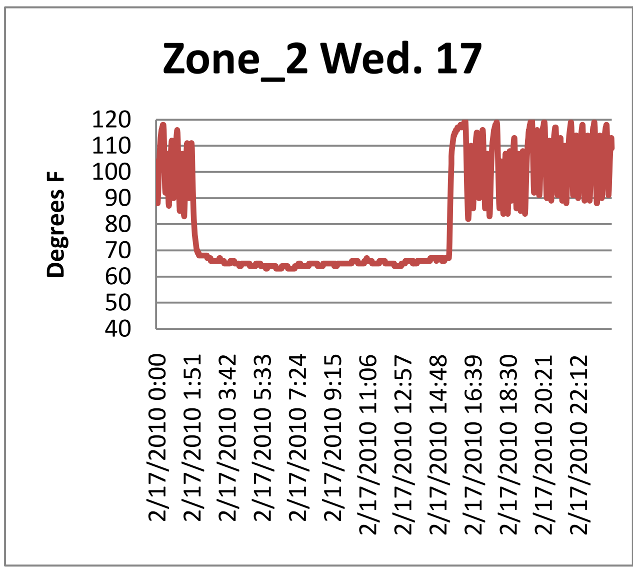
We did not include the lobby HVAC unit because we were suspicious that the data we got back from those ducts had been adversely effected by some factor proximity to the front door. Where other systems showed obvious sharp temperature spikes, the lobby unit showed no such behavior; recorded temperature in the duct only varied by 10-15 degrees. Assuming zero energy use at the minimum and maximum energy use (108,000 BTUs per hour in this case) with only 15 degrees difference between minimum and maxiumum recorded values would not offer an accurate representation of the energy use or cost of this unit. Omitting that HVAC system was of little consequence because the temperature data also pointed towards minimal operation time.

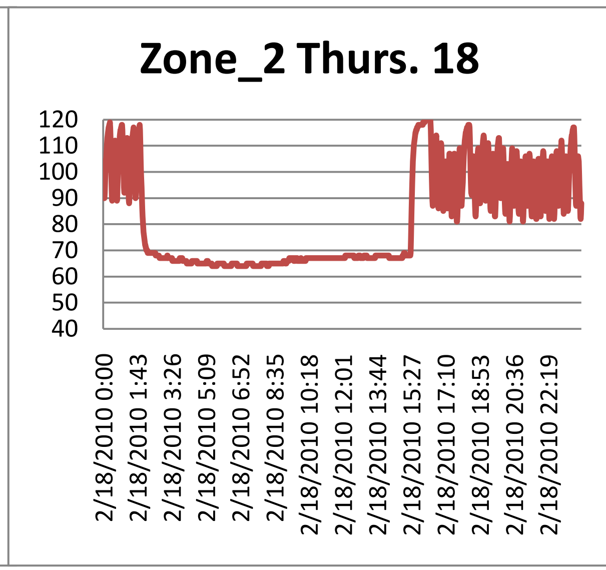
HVAC Temperature Graphs All Units 2/17-2/24

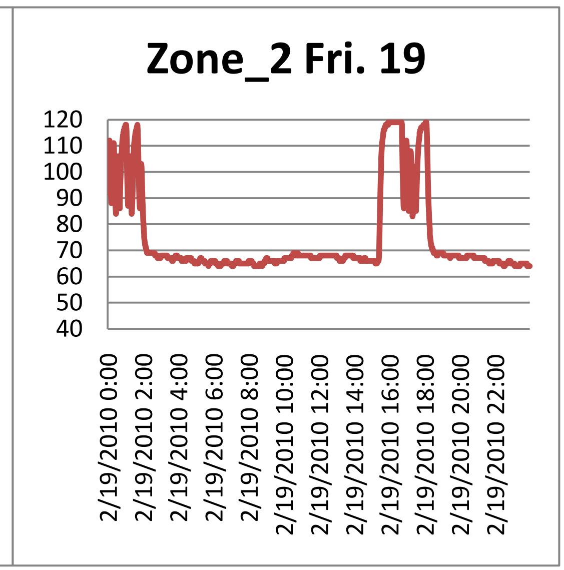


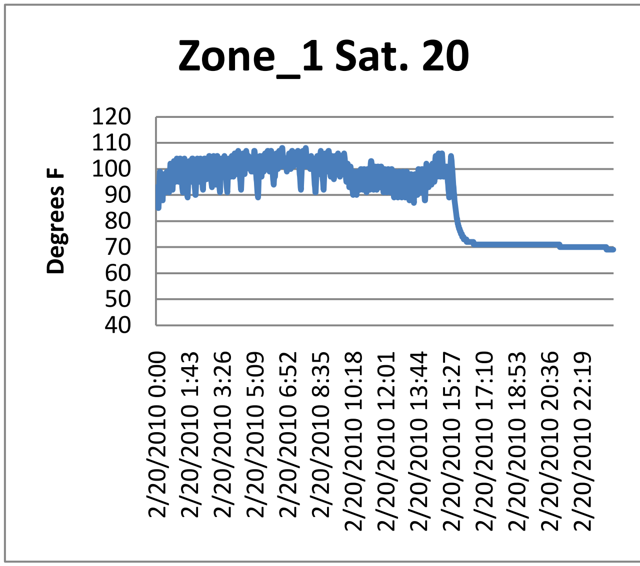








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110
100
90
80
70
60
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40
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2/20/2010 5:09
2/20/2010 6:52
2/20/2010 8:35
2/20/2010 10:18
2/20/2010 12:01
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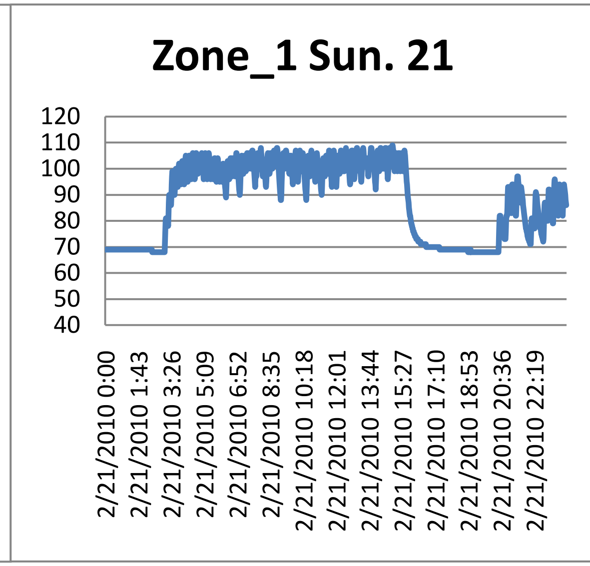
2/20/2010 22:19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2/21/2010 5:09
2/21/2010 6:52
2/21/2010 8:35
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2/21/2010 12:01
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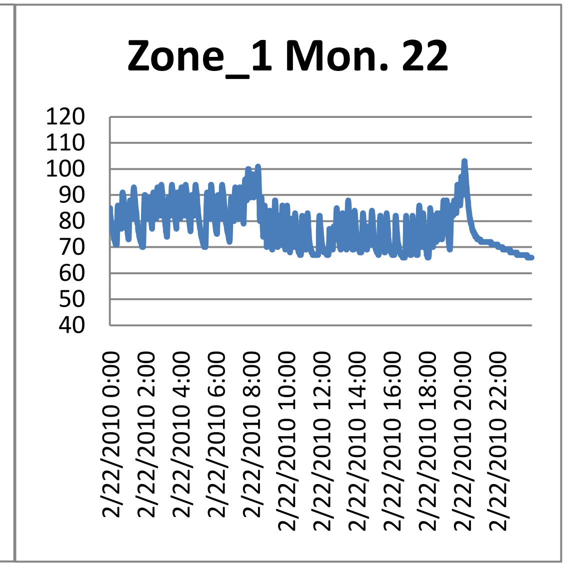
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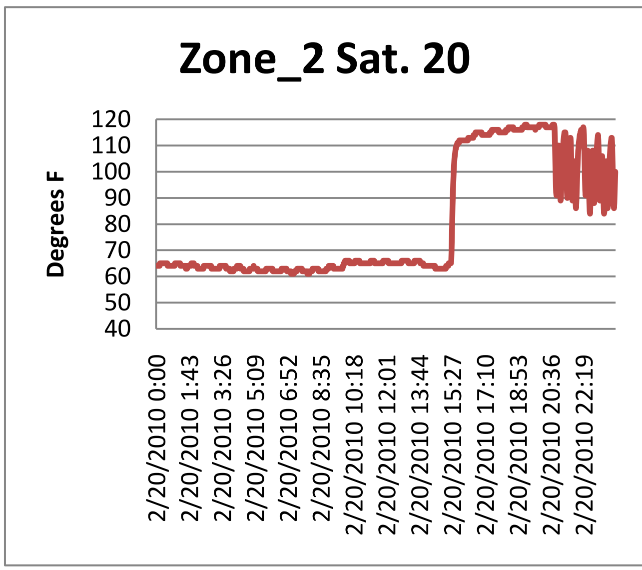
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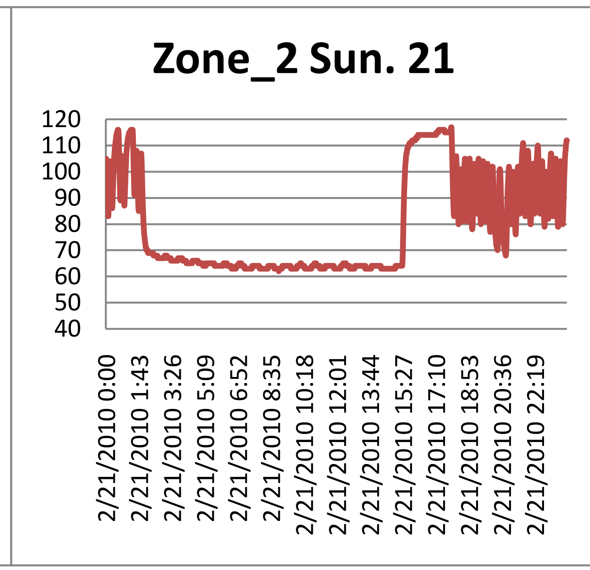
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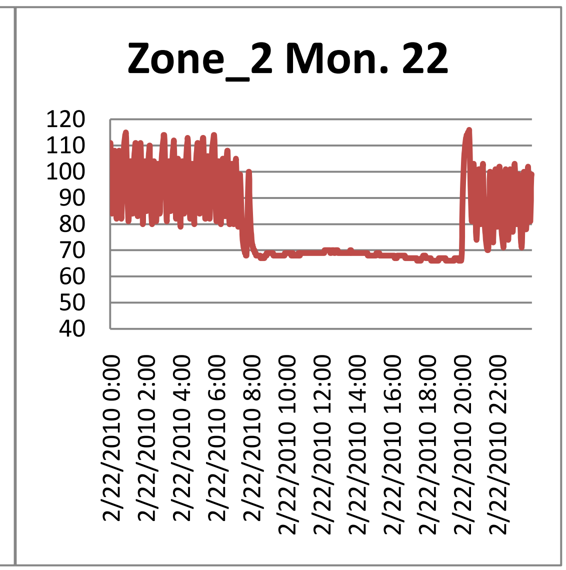
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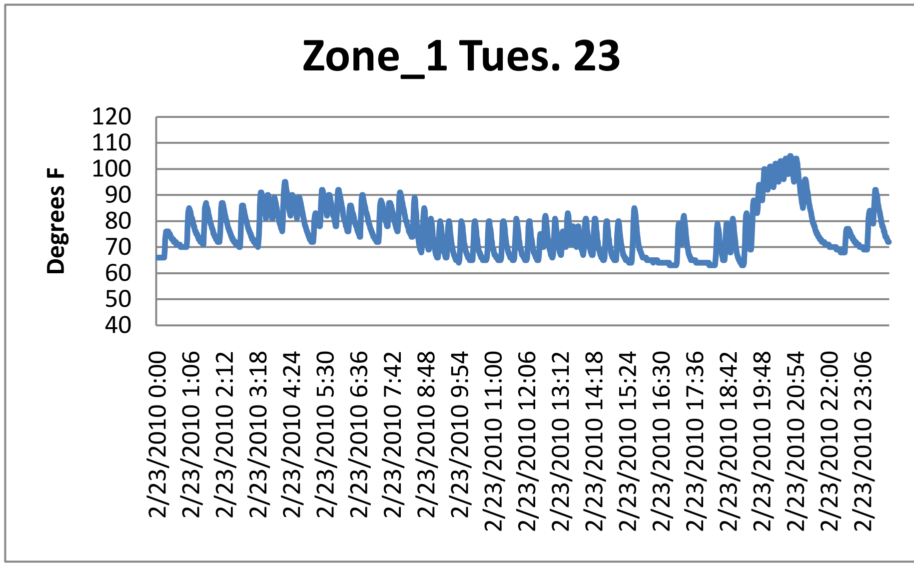
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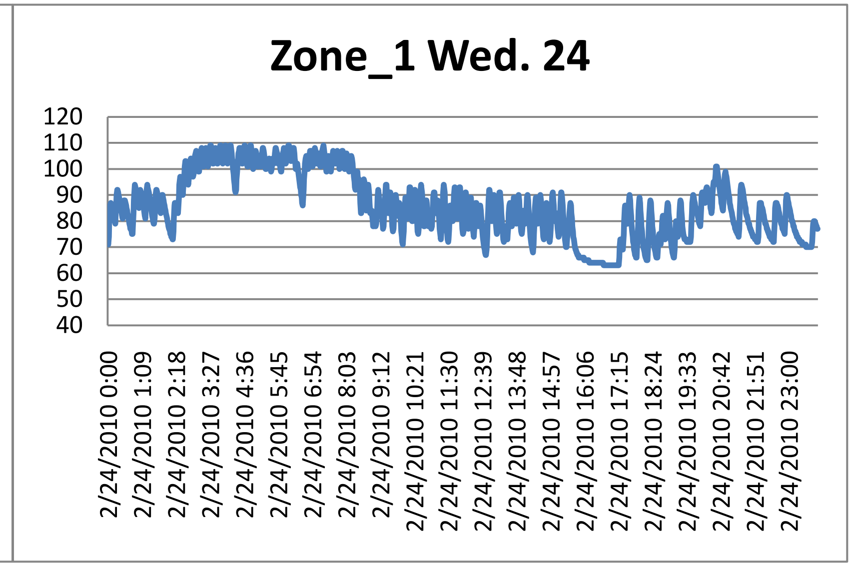
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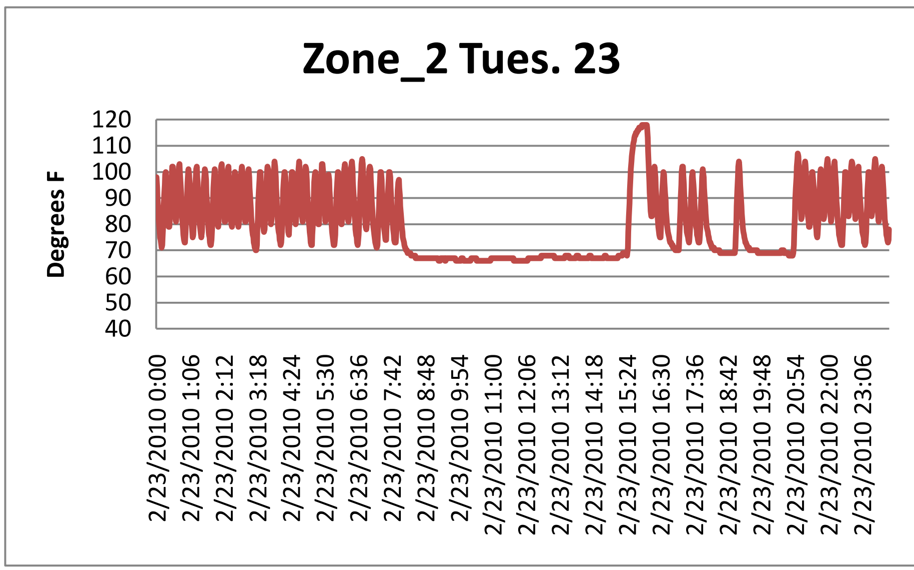
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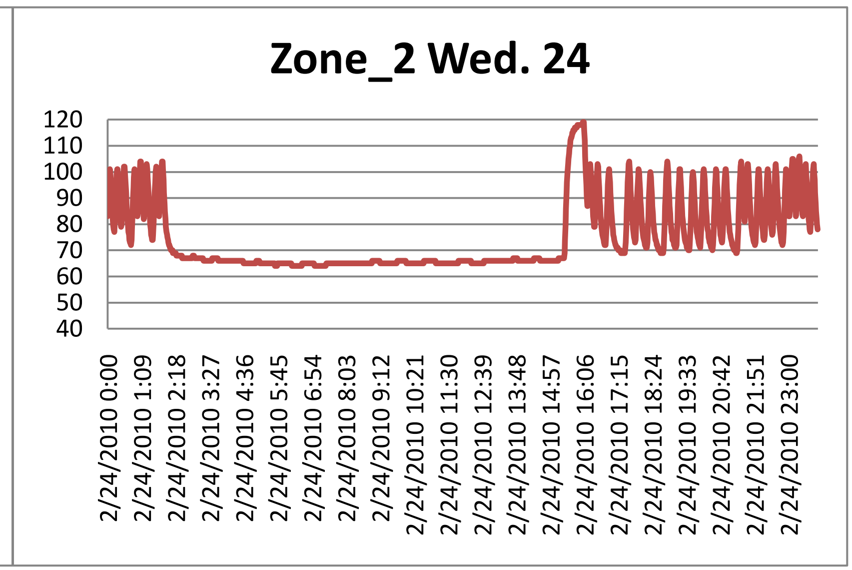
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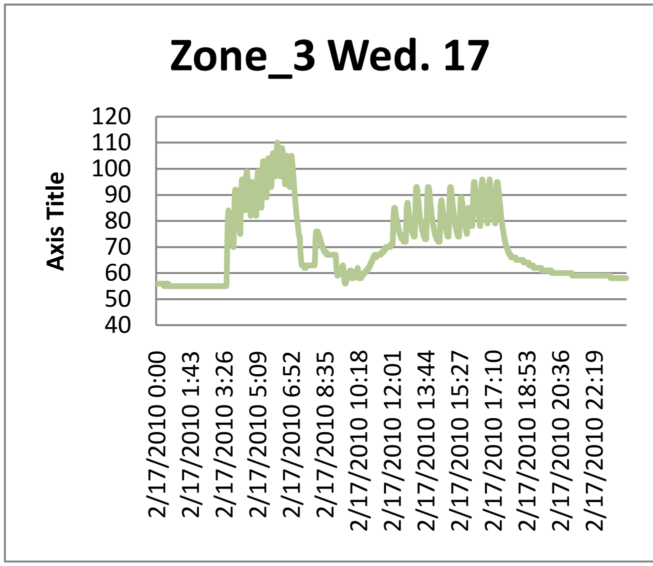
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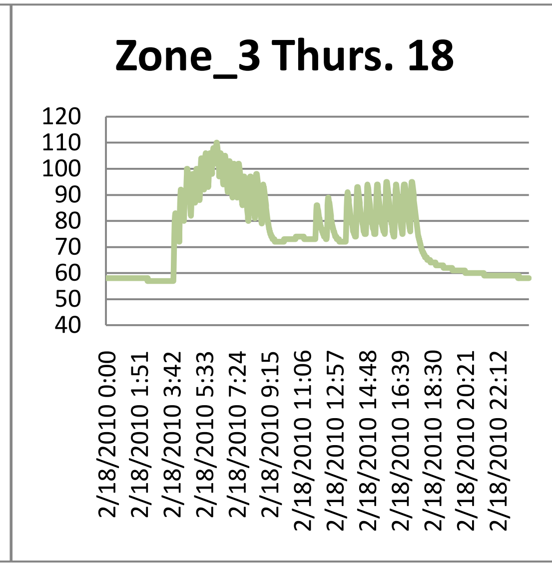
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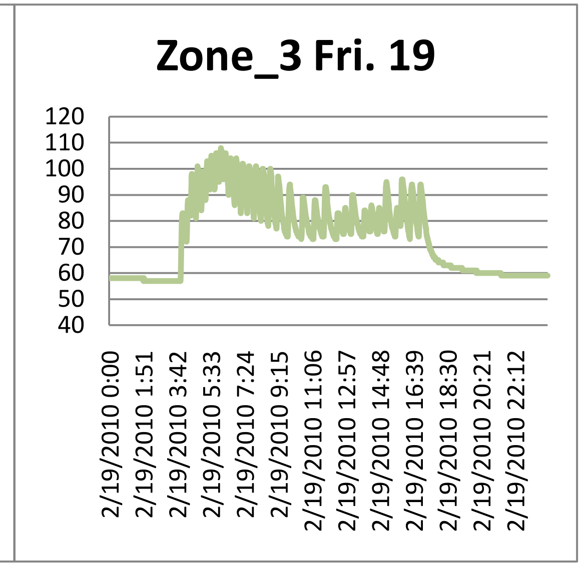
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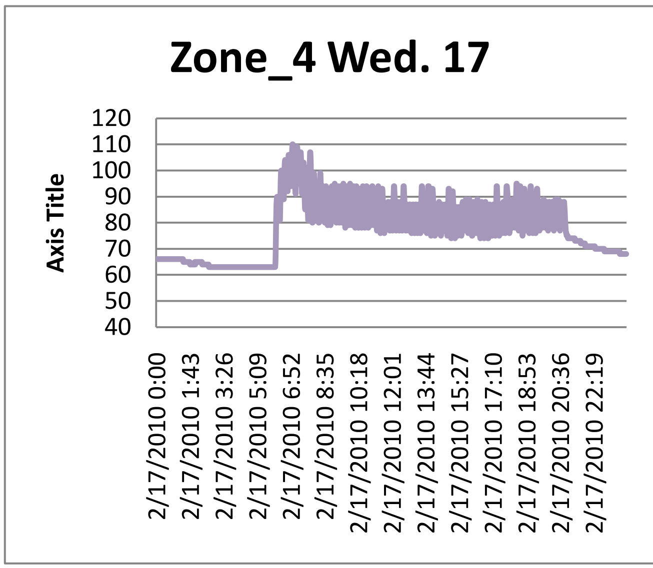
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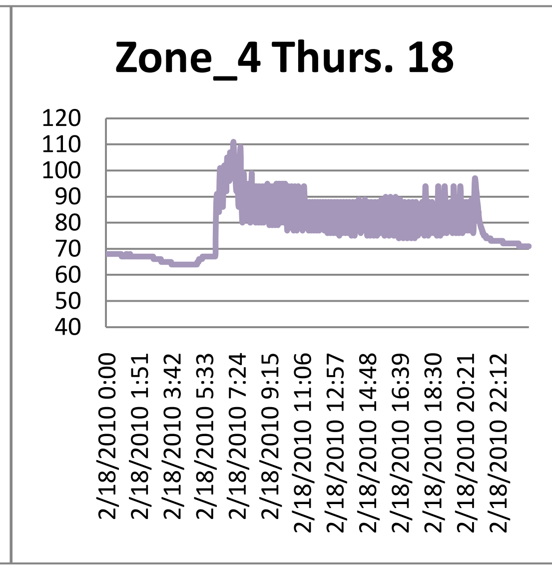
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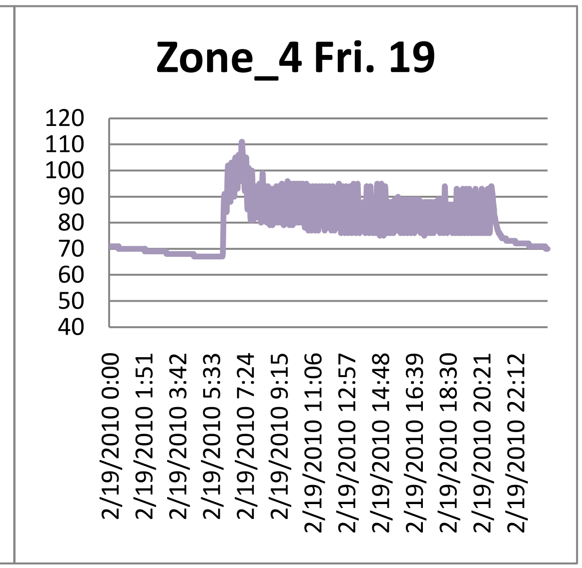
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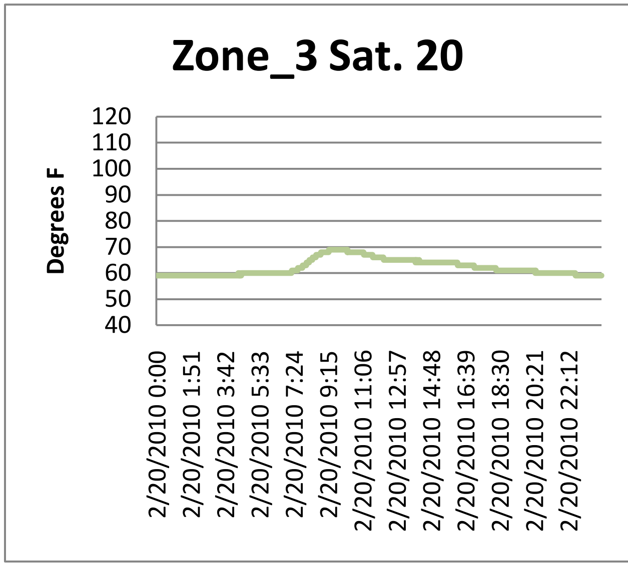
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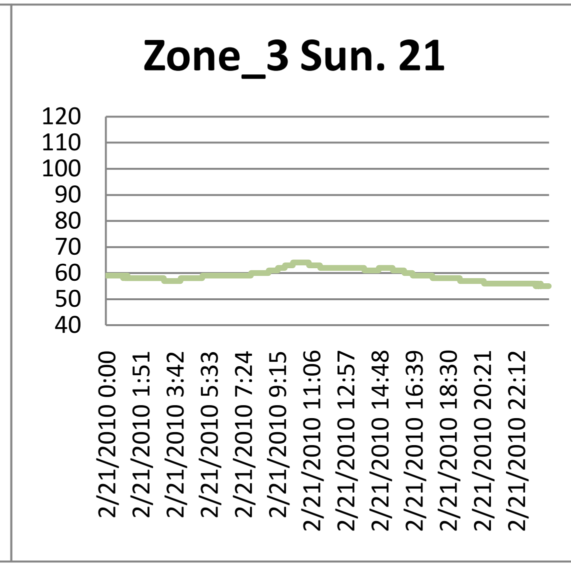
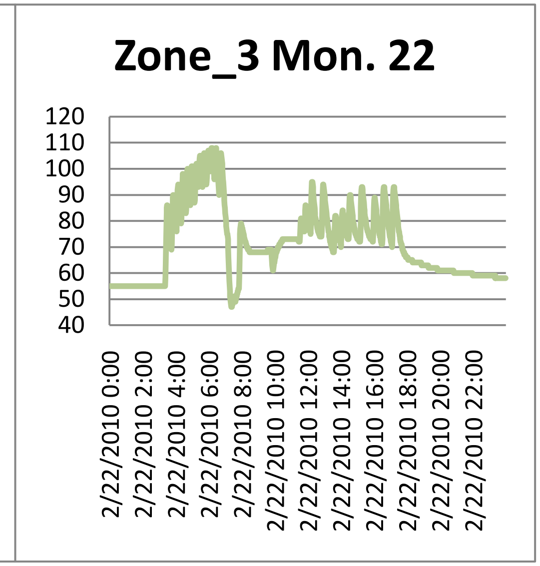
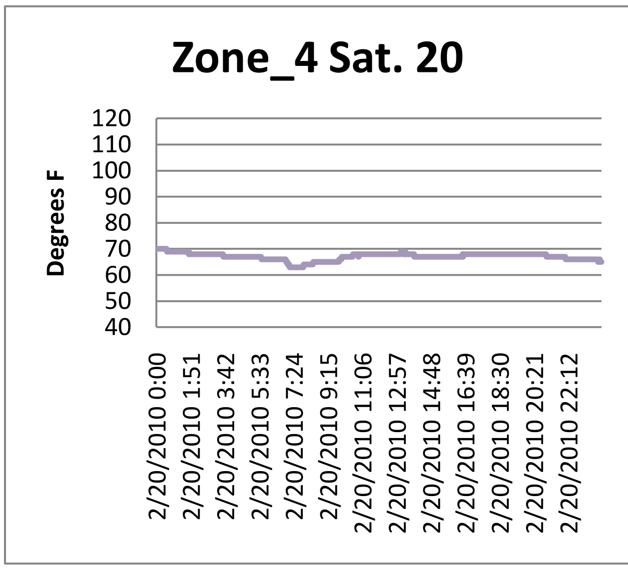
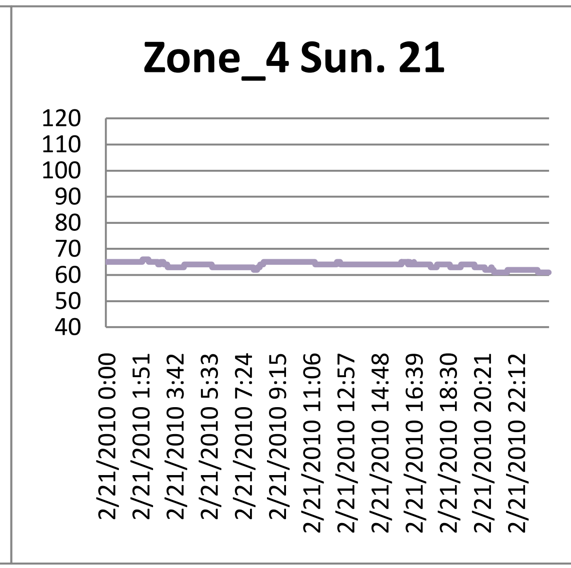
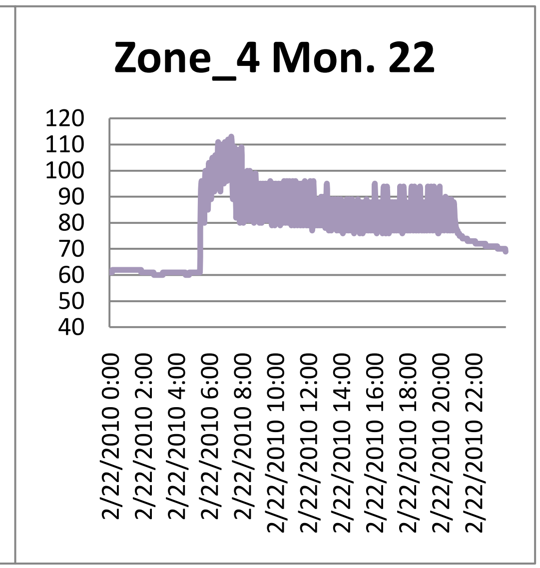
2/20/2010 20:21
2/20/2010 22:12

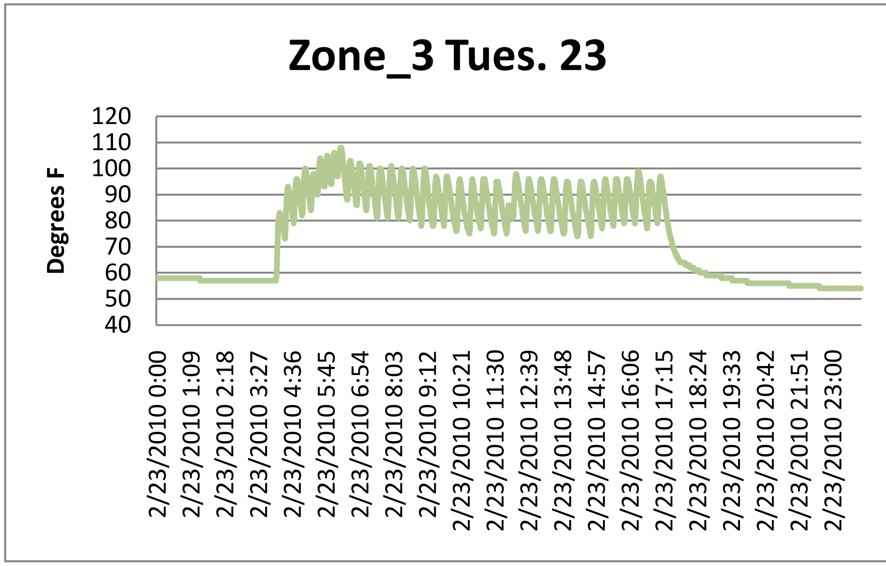

Zone_3 Sun. 21
120
110
100
90
80
70
60
50
40
2/21/2010 0:00
2/21/2010 1:51
2/21/2010 3:42
2/21/2010 5:33
2/21/2010 7:24
2/21/2010 9:15
2/21/2010 11:06
2/21/2010 12:57
2/21/2010 14:48
2/21/2010 16:39
2/21/2010 18:30
2/21/2010 20:21
2/21/2010 22:12

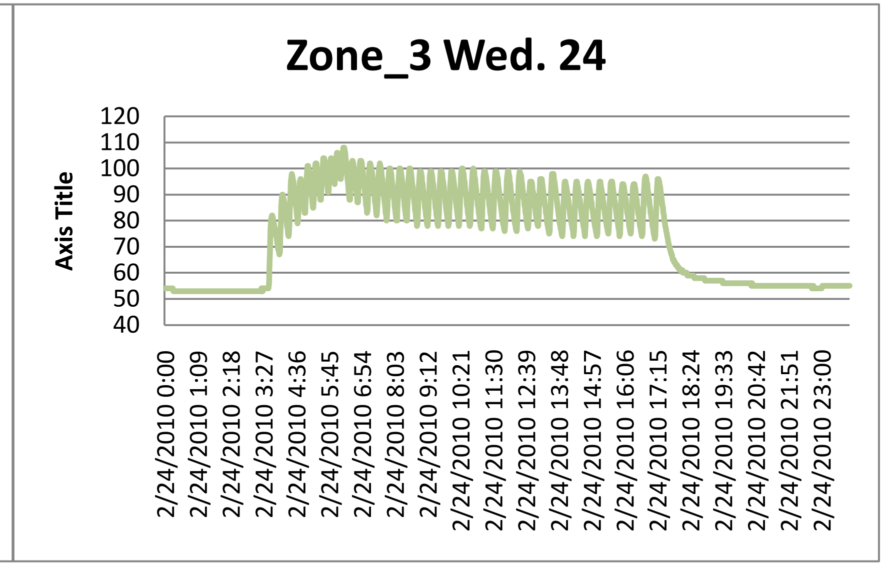

Zone_3 Mon. 22
120
110
100
90
80
70
60
50
40
2/22/2010 0:00
2/22/2010 2:00
2/22/2010 4:00
2/22/2010 6:00
2/22/2010 8:00
2/22/2010 10:00
2/22/2010 12:00
2/22/2010 14:00
2/22/2010 16:00
2/22/2010 18:00
2/22/2010 20:00
2/22/2010 22:00

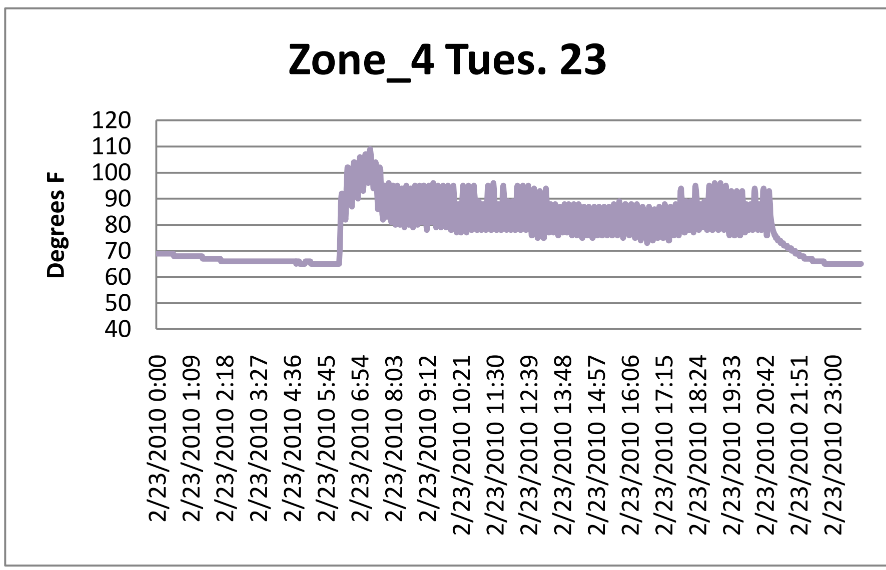

Zone_4 Sat. 20
Degrees F
120
110
100
90
80
70
60
50
40
2/20/2010 0:00
2/20/2010 1:51
2/20/2010 3:42
2/20/2010 5:33
2/20/2010 7:24
2/20/2010 9:15
2/20/2010 11:06
2/20/2010 12:57
2/20/2010 14:48
2/20/2010 16:39
2/20/2010 18:30
2/20/2010 20:21
2/20/2010 22:12

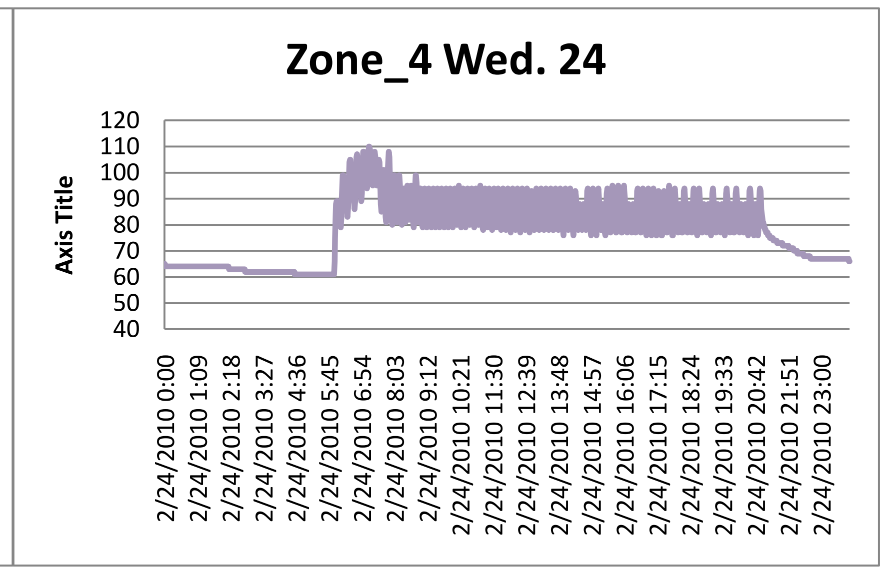

Zone_4 Sun. 21
120
110
100
90
80
70
60
50
40
2/21/2010 0:00
2/21/2010 1:51
2/21/2010 3:42
2/21/2010 5:33
2/21/2010 7:24
2/21/2010 9:15
2/21/2010 11:06
2/21/2010 12:57
2/21/2010 14:48
2/21/2010 16:39
2/21/2010 18:30
2/21/2010 20:21
2/21/2010 22:12

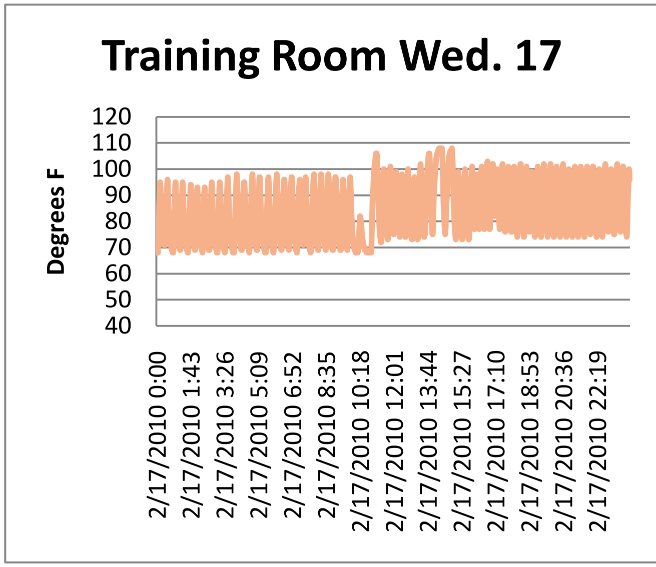

Zone_4 Mon. 22
120
110
100
90
80
70
60
50
40
2/22/2010 0:00
2/22/2010 2:00
2/22/2010 4:00
2/22/2010 6:00
2/22/2010 8:00
2/22/2010 10:00
2/22/2010 12:00
2/22/2010 14:00
2/22/2010 16:00
2/22/2010 18:00
2/22/2010 20:00
2/22/2010 22:00

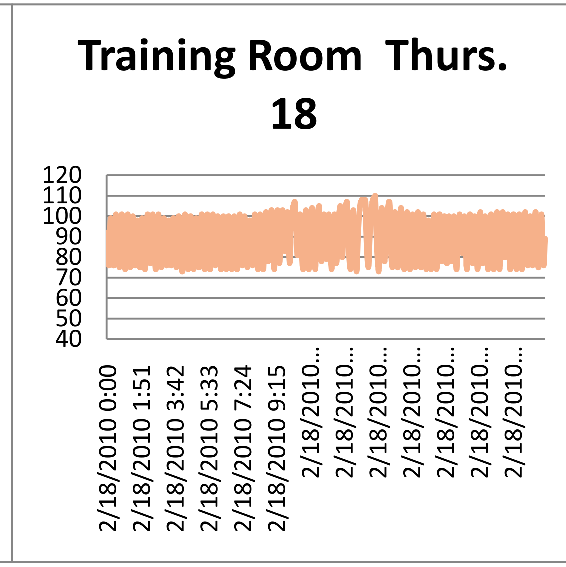

Zone_3 Tues. 23
Degrees F
120
110
100
90
80
70
60
50
40
2/23/2010 0:00
2/23/2010 1:09
2/23/2010 2:18
2/23/2010 3:27
2/23/2010 4:36
2/23/2010 5:45
2/23/2010 6:54
2/23/2010 8:03
2/23/2010 9:12
2/23/2010 10:21
2/23/2010 11:30
2/23/2010 12:39
2/23/2010 13:48
2/23/2010 14:57
2/23/2010 16:06
2/23/2010 17:15
2/23/2010 18:24
2/23/2010 19:33
2/23/2010 20:42
2/23/2010 21:51
2/23/2010 23:00

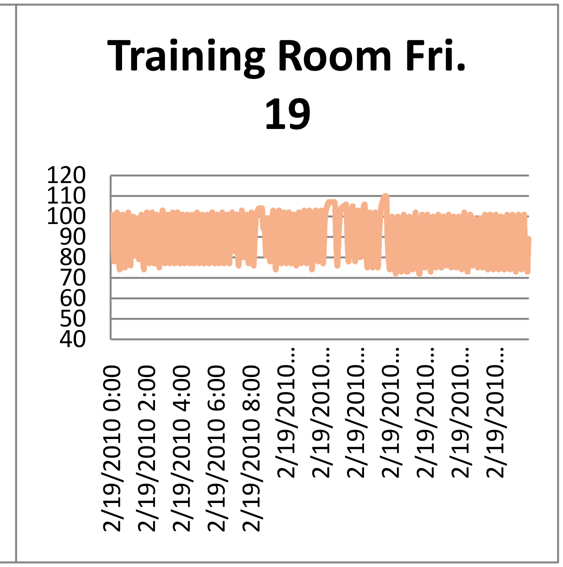

Zone_3 Wed. 24
Axis Title
120
110
100
90
80
70
60
50
40
2/24/2010 0:00
2/24/2010 1:09
2/24/2010 2:18
2/24/2010 3:27
2/24/2010 4:36
2/24/2010 5:45
2/24/2010 6:54
2/24/2010 8:03
2/24/2010 9:12
2/24/2010 10:21
2/24/2010 11:30
2/24/2010 12:39
2/24/2010 13:48
2/24/2010 14:57
2/24/2010 16:06
2/24/2010 17:15
2/24/2010 18:24
2/24/2010 19:33
2/24/2010 20:42
2/24/2010 21:51
2/24/2010 23:00

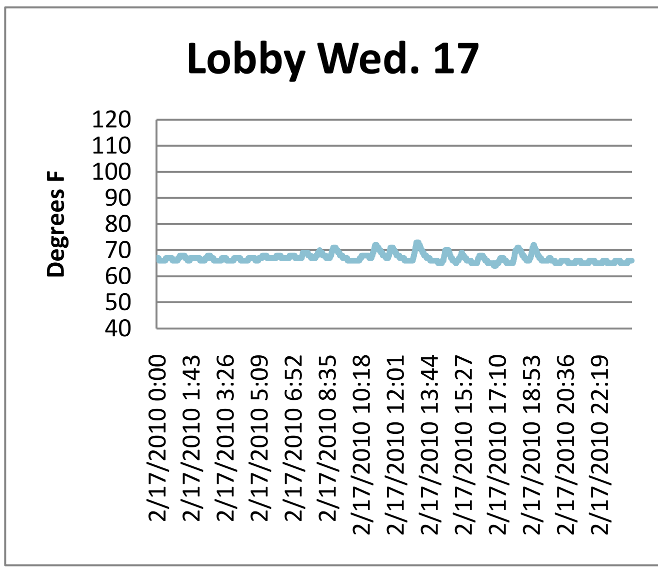

Zone_4 Tues. 23
Degrees F
120
110
100
90
80
70
60
50
40
2/23/2010 0:00
2/23/2010 1:09
2/23/2010 2:18
2/23/2010 3:27
2/23/2010 4:36
2/23/2010 5:45
2/23/2010 6:54
2/23/2010 8:03
2/23/2010 9:12
2/23/2010 10:21
2/23/2010 11:30
2/23/2010 12:39
2/23/2010 13:48
2/23/2010 14:57
2/23/2010 16:06
2/23/2010 17:15
2/23/2010 18:24
2/23/2010 19:33
2/23/2010 20:42
2/23/2010 21:51
2/23/2010 23:00

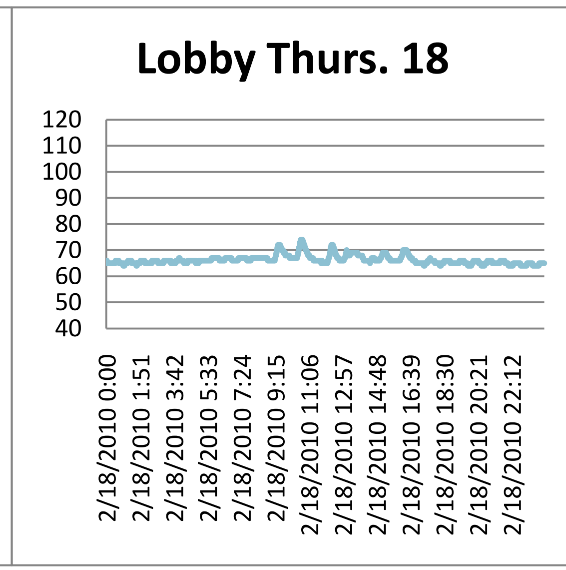

Zone_4 Wed. 24
Axis Title
120
110
100
90
80
70
60
50
40
2/24/2010 0:00
2/24/2010 1:09
2/24/2010 2:18
2/24/2010 3:27
2/24/2010 4:36
2/24/2010 5:45
2/24/2010 6:54
2/24/2010 8:03
2/24/2010 9:12
2/24/2010 10:21
2/24/2010 11:30
2/24/2010 12:39
2/24/2010 13:48
2/24/2010 14:57
2/24/2010 16:06
2/24/2010 17:15
2/24/2010 18:24
2/24/2010 19:33
2/24/2010 20:42
2/24/2010 21:51
2/24/2010 23:00


Training Room Wed. 17
Degrees F
120
110
100
90
80
70
60
50
40
2/17/2010 0:00
2/17/2010 1:43
2/17/2010 3:26
2/17/2010 5:09
2/17/2010 6:52
2/17/2010 8:35
2/17/2010 10:18
2/17/2010 12:01
2/17/2010 13:44
2/17/2010 15:27
2/17/2010 17:10
2/17/2010 18:53
2/17/2010 20:36
2/17/2010 22:19


Training Room Thurs. 18
120
110
100
90
80
70
60
50
40
2/18/2010 0:00
2/18/2010 1:51
2/18/2010 3:42
2/18/2010 5:33
2/18/2010 7:24
2/18/2010 9:15
2/18/2010…
2/18/2010…
2/18/2010…
2/18/2010…
2/18/2010…
2/18/2010…
2/18/2010…


Training Room Fri. 19
120
110
100
90
80
70
60
50
40
2/19/2010 0:00
2/19/2010 2:00
2/19/2010 4:00
2/19/2010 6:00
2/19/2010 8:00
2/19/2010…
2/19/2010…
2/19/2010…
2/19/2010…
2/19/2010…
2/19/2010…
2/19/2010…


Lobby Wed. 17
Degrees F
120
110
100
90
80
70
60
50
40
2/17/2010 0:00
2/17/2010 1:43
2/17/2010 3:26
2/17/2010 5:09
2/17/2010 6:52
2/17/2010 8:35
2/17/2010 10:18
2/17/2010 12:01
2/17/2010 13:44
2/17/2010 15:27
2/17/2010 17:10
2/17/2010 18:53
2/17/2010 20:36
2/17/2010 22:19


Lobby Thurs. 18
120
110
100
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80
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60
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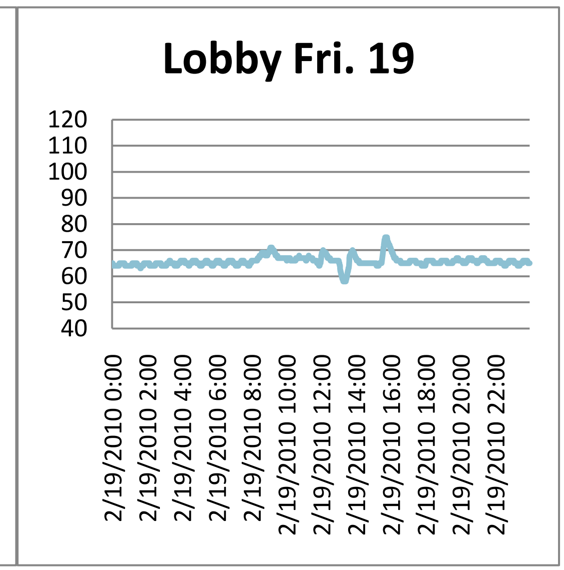
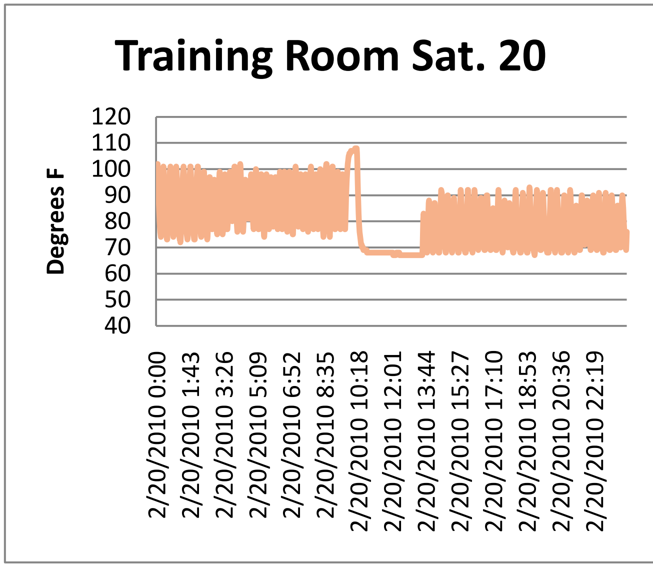
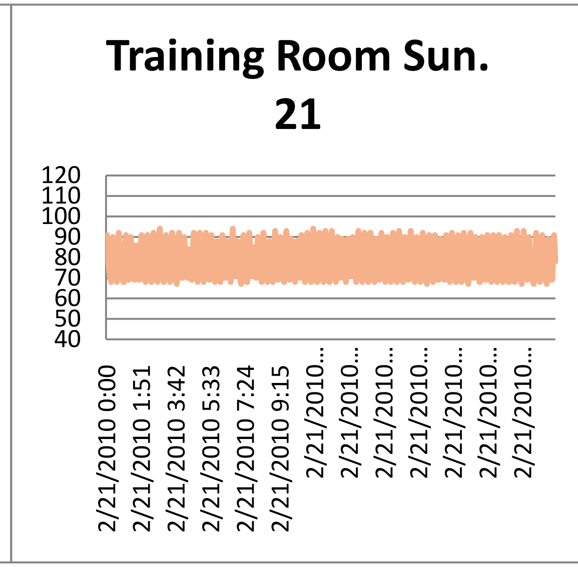
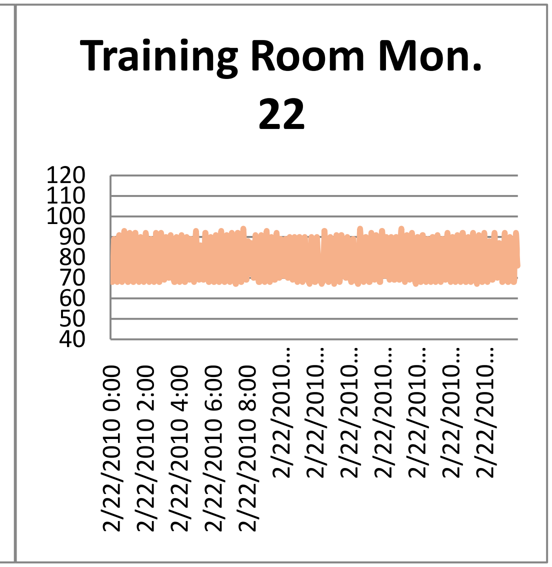
40
2/18/2010 0:00
2/18/2010 1:51
2/18/2010 3:42
2/18/2010 5:33
2/18/2010 7:24
2/18/2010 9:15
2/18/2010 11:06
2/18/2010 12:57
2/18/2010 14:48
2/18/2010 16:39
2/18/2010 18:30
2/18/2010 20:21
2/18/2010 22:12


Lobby Fri. 19
120
110
100
90
80
70
60
50
40
2/19/2010 0:00
2/19/2010 2:00
2/19/2010 4:00
2/19/2010 6:00
2/19/2010 8:00
2/19/2010 10:00
2/19/2010 12:00
2/19/2010 14:00
2/19/2010 16:00
2/19/2010 18:00
2/19/2010 20:00
2/19/2010 22:00


Training Room Sat. 20
Degrees F
120
110
100
90
80
70
60
50
40
2/20/2010 0:00
2/20/2010 1:43
2/20/2010 3:26
2/20/2010 5:09
2/20/2010 6:52
2/20/2010 8:35
2/20/2010 10:18
2/20/2010 12:01
2/20/2010 13:44
2/20/2010 15:27
2/20/2010 17:10
2/20/2010 18:53
2/20/2010 20:36
2/20/2010 22:19


Training Room Sun. 21
120
110
100
90
80
70
60
50
40
2/21/2010 0:00
2/21/2010 1:51
2/21/2010 3:42
2/21/2010 5:33
2/21/2010 7:24
2/21/2010 9:15
2/21/2010...
2/21/2010...
2/21/2010...
2/21/2010...
2/21/2010...
2/21/2010...
2/21/2010...


Training Room Mon. 22
120
110
100
90
80
70
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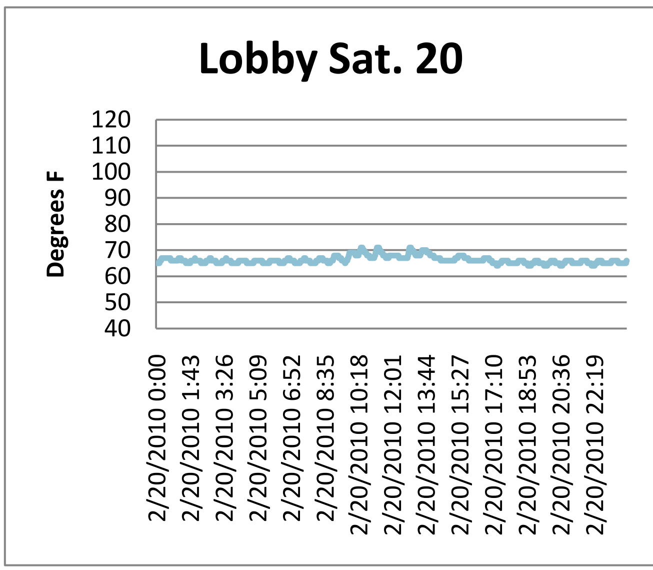
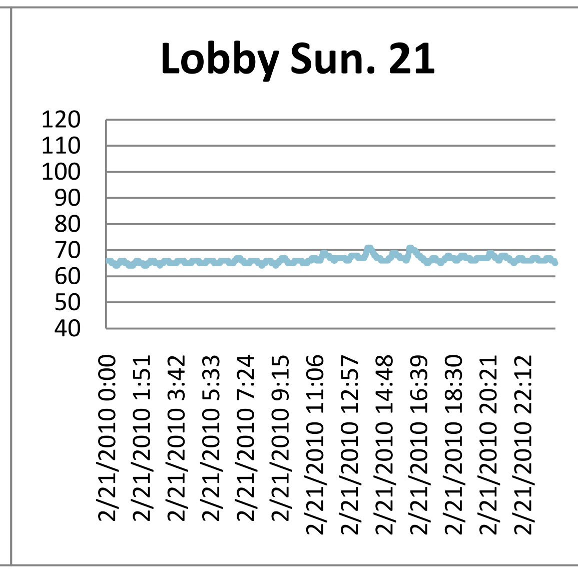
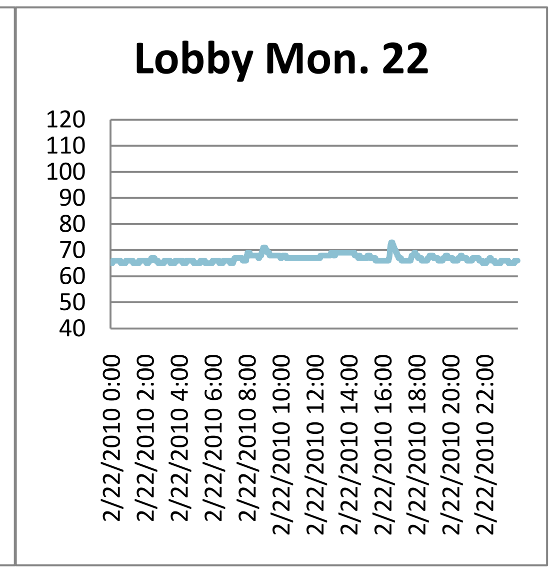
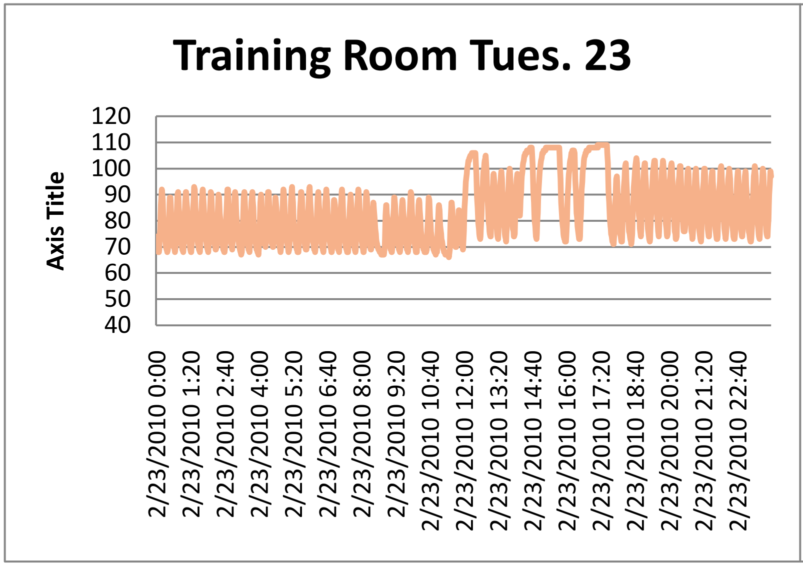
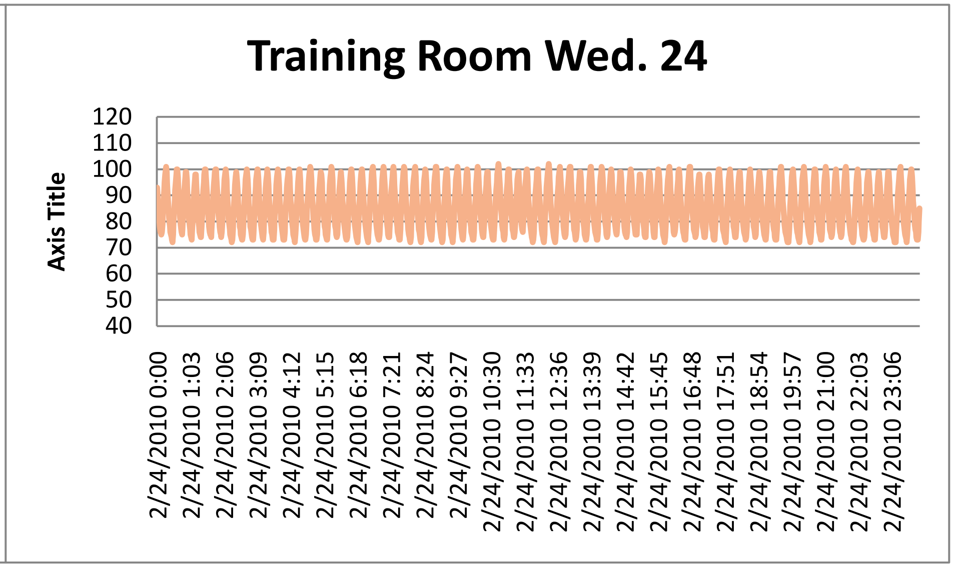
40
2/22/2010 0:00
2/22/2010 2:00
2/22/2010 4:00
2/22/2010 6:00
2/22/2010 8:00
2/22/2010...
2/22/2010...
2/22/2010...
2/22/2010...
2/22/2010...
2/22/2010...
2/22/2010...

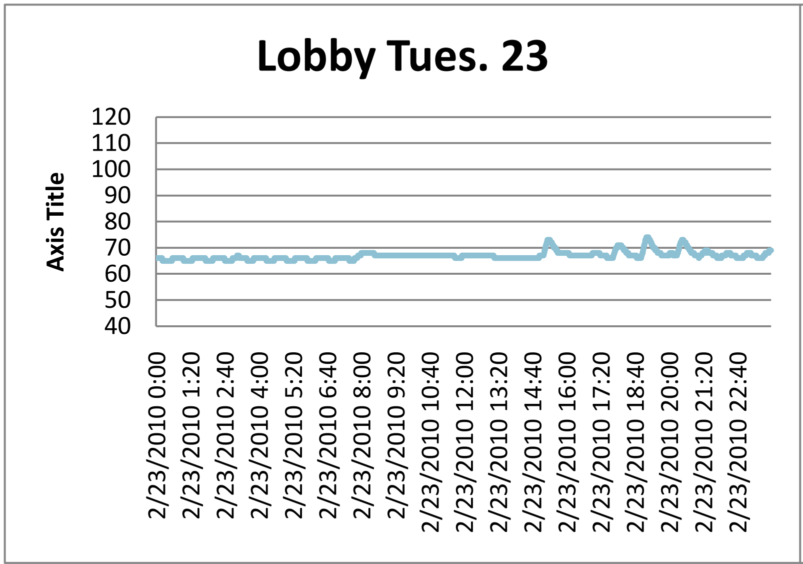

Lobby Sat. 20
Degrees F
120
110
100
90
80
70
60
50
40
2/20/2010 0:00
2/20/2010 1:43
2/20/2010 3:26
2/20/2010 5:09
2/20/2010 6:52
2/20/2010 8:35
2/20/2010 10:18
2/20/2010 12:01
2/20/2010 13:44
2/20/2010 15:27
2/20/2010 17:10
2/20/2010 18:53
2/20/2010 20:36
2/20/2010 22:19

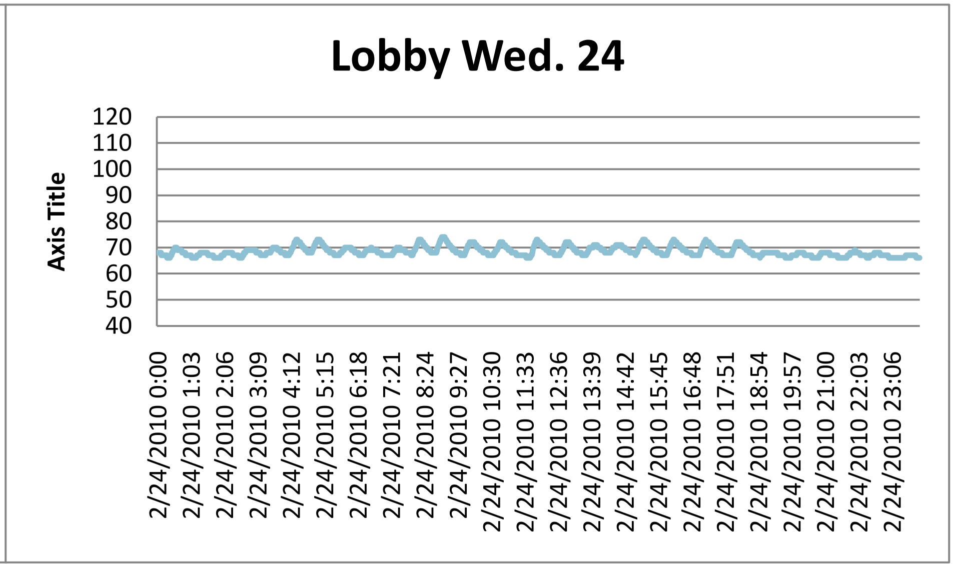

Lobby Sun. 21
120
110
100
90
80
70
60
50
40
2/21/2010 0:00
2/21/2010 1:51
2/21/2010 3:42
2/21/2010 5:33
2/21/2010 7:24
2/21/2010 9:15
2/21/2010 11:06
2/21/2010 12:57
2/21/2010 14:48
2/21/2010 16:39
2/21/2010 18:30
2/21/2010 20:21
2/21/2010 22:12


Lobby Mon. 22
120
110
100
90
80
70
60
50
40
2/22/2010 0:00
2/22/2010 2:00
2/22/2010 4:00
2/22/2010 6:00
2/22/2010 8:00
2/22/2010 10:00
2/22/2010 12:00
2/22/2010 14:00
2/22/2010 16:00
2/22/2010 18:00
2/22/2010 20:00
2/22/2010 22:00


Training Room Tues. 23
Axis Title
120
110
100
90
80
70
60
50
40
2/23/2010 0:00
2/23/2010 1:20
2/23/2010 2:40
2/23/2010 4:00
2/23/2010 5:20
2/23/2010 6:40
2/23/2010 8:00
2/23/2010 9:20
2/23/2010 10:40
2/23/2010 12:00
2/23/2010 13:20
2/23/2010 14:40
2/23/2010 16:00
2/23/2010 17:20
2/23/2010 18:40
2/23/2010 20:00
2/23/2010 21:20
2/23/2010 22:40


Training Room Wed. 24
Axis Title
120
110
100
90
80
70
60
50
40
2/24/2010 0:00
2/24/2010 1:03
2/24/2010 2:06
2/24/2010 3:09
2/24/2010 4:12
2/24/2010 5:15
2/24/2010 6:18
2/24/2010 7:21
2/24/2010 8:24
2/24/2010 9:27
2/24/2010 10:30
2/24/2010 11:33
2/24/2010 12:36
2/24/2010 13:39
2/24/2010 14:42
2/24/2010 15:45
2/24/2010 16:48
2/24/2010 17:51
2/24/2010 18:54
2/24/2010 19:57
2/24/2010 21:00
2/24/2010 22:03
2/24/2010 23:06

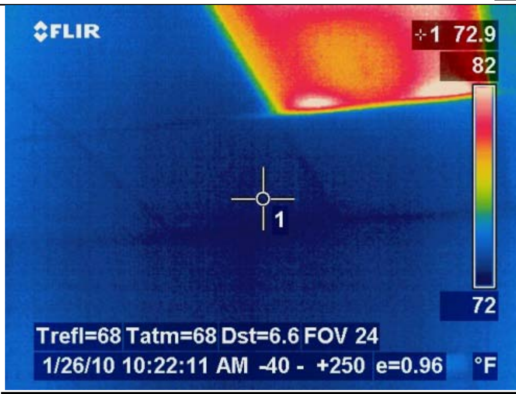

Lobby Tues. 23
Axis Title
120
110
100
90
80
70
60
50
40
2/23/2010 0:00
2/23/2010 1:20
2/23/2010 2:40
2/23/2010 4:00
2/23/2010 5:20
2/23/2010 6:40
2/23/2010 8:00
2/23/2010 9:20
2/23/2010 10:40
2/23/2010 12:00
2/23/2010 13:20
2/23/2010 14:40
2/23/2010 16:00
2/23/2010 17:20
2/23/2010 18:40
2/23/2010 20:00
2/23/2010 21:20
2/23/2010 22:40


Lobby Wed. 24
Axis Title
120
110
100
90
80
70
60
50
40
2/24/2010 0:00
2/24/2010 1:03
2/24/2010 2:06
2/24/2010 3:09
2/24/2010 4:12
2/24/2010 5:15
2/24/2010 6:18
2/24/2010 7:21
2/24/2010 8:24
2/24/2010 9:27
2/24/2010 10:30
2/24/2010 11:33
2/24/2010 12:36
2/24/2010 13:39
2/24/2010 14:42
2/24/2010 15:45
2/24/2010 16:48
2/24/2010 17:51
2/24/2010 18:54
2/24/2010 19:57
2/24/2010 21:00
2/24/2010 22:03
2/24/2010 23:06

Appendix: C

Thermal Images

Thermal Pictures

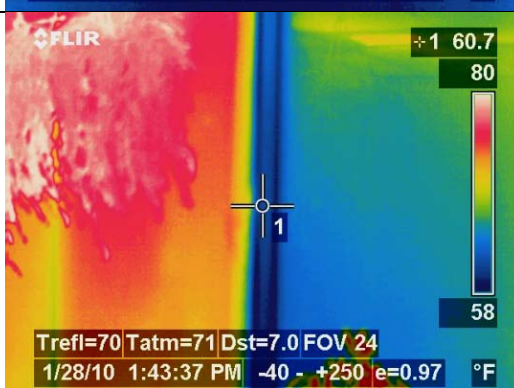


1/26/2010

Ceiling and Light

1/26/2010

Ceiling and Light

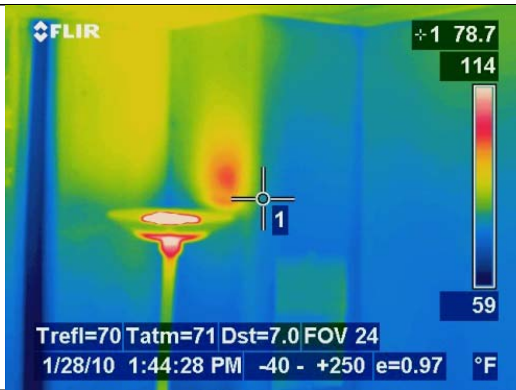


1/28/2010

Room 406 Window

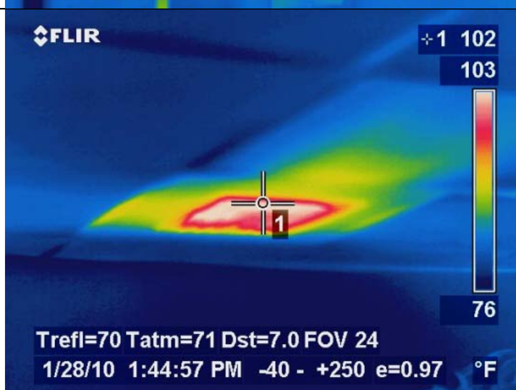
1/28/2010

Room 406 Window



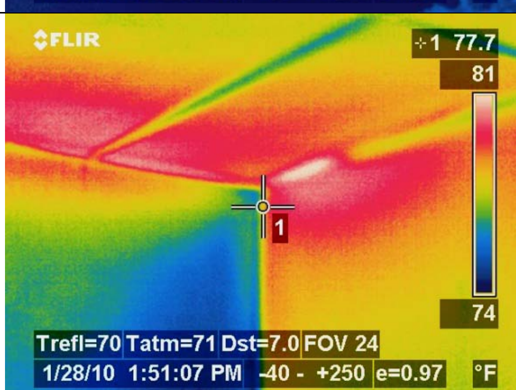
1/28/2010

Room 406 Light



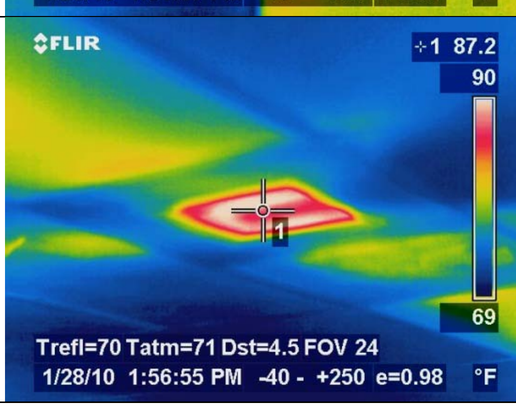
1/28/2010

HVAC Vent



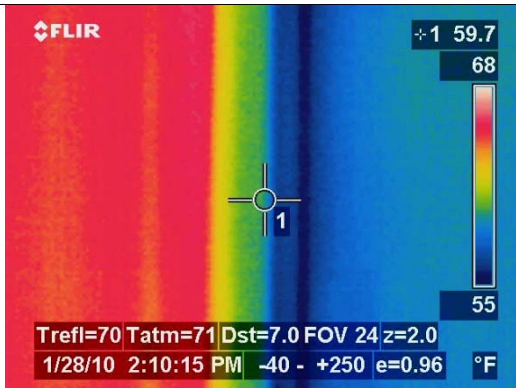
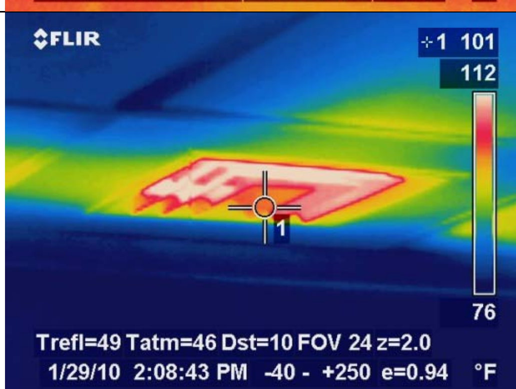
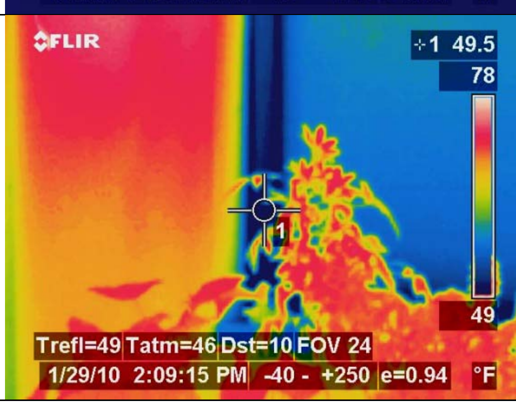
1/28/2010

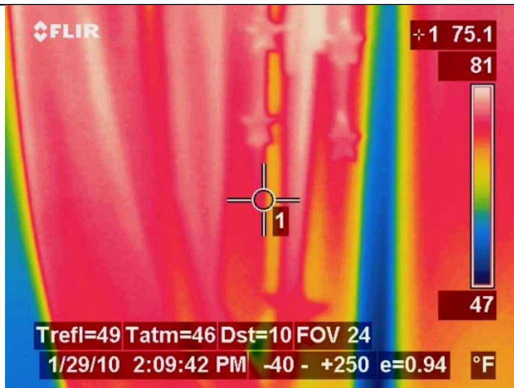
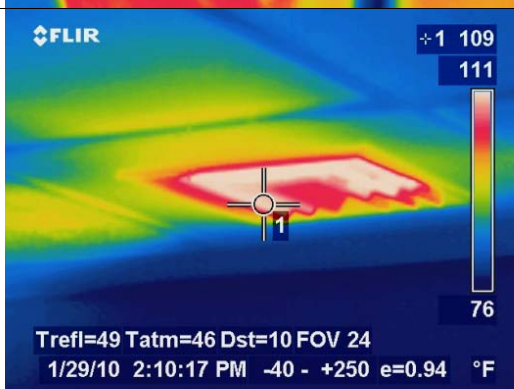
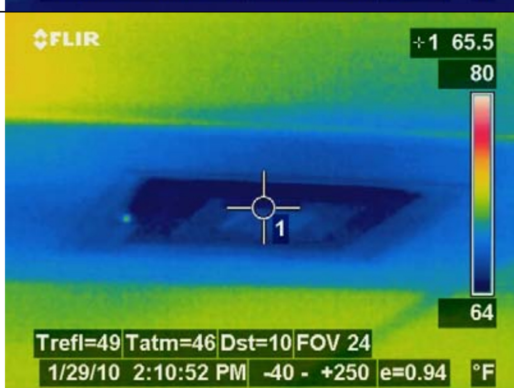
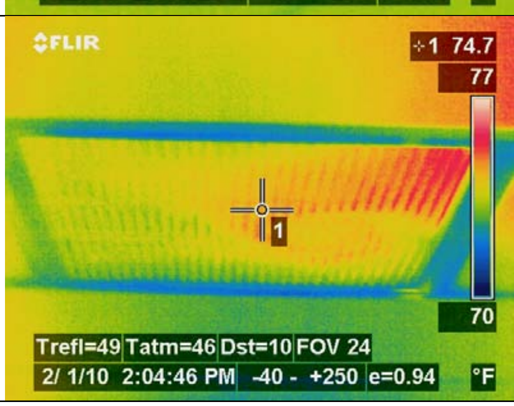
Room Corner



1/28/2010

HVAC Vent

	1/28/2010 Window
	1/28/2010 Room 406 Window and Plants
	1/29/2010 HVAC vent (on)
	1/29/2010 Room 406 Window and Plant

	1/29/2010 Room 406 Curtains
	1/29/2010 HVAC Vent (on)
	1/29/2010 HVAC Vent (off)
	2/1/2010 HVAC Intake

	2/1/2010 Room 212 Water Damage
	2/1/2010 HVAC Vent (off)
	2/1/2010 Hallway Window Near Room 302
	2/1/2010 Hallway Window Near Room 302

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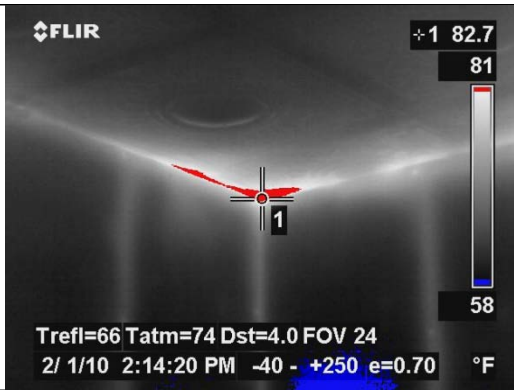
<tr><td>
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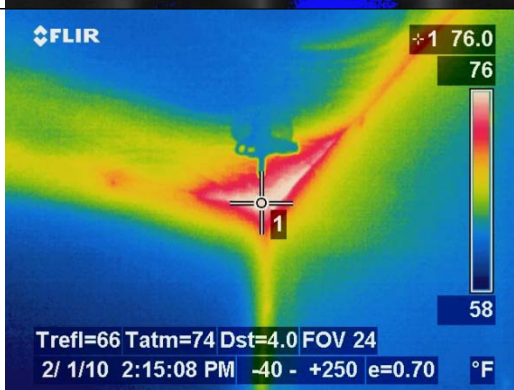
Emergency Exit Corridor Corner</td></tr>
<tr><td>
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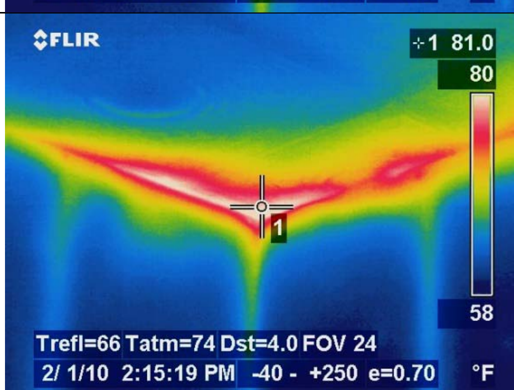
Emergency Exit Corridor Corner</td></tr>
<tr><td>
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Emergency Exit Corridor Corner</td></tr>
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Emergency Exit Outside Door (bottom)</td></tr>
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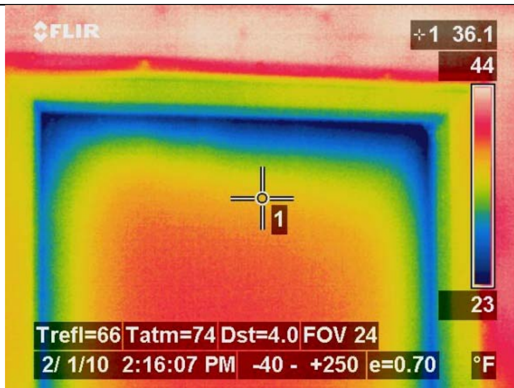
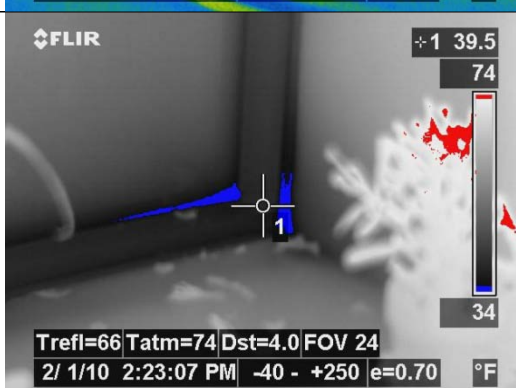
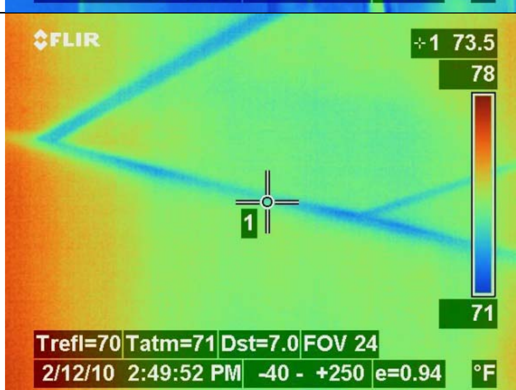
	2/1/2010 Emergency Exit Outside Door (top)
	2/1/2010 Emergency Exit Corridor Electrical Box
	2/1/2010 Hallway Window Near Room 302
	2/1/2010 HVAC Vent

2/1/2010

Ceiling Thermal Leak

2/12/2010

Room 407 Corner

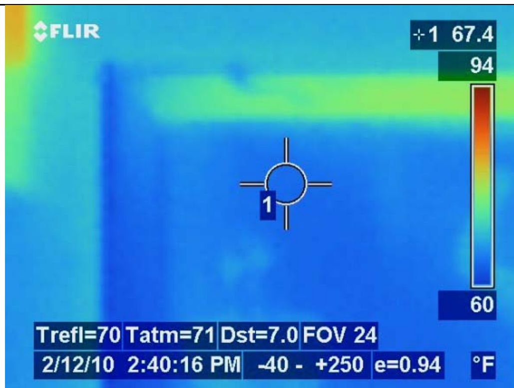


2/12/2010

Ceiling

2/12/2010

Front Entrance (Pharmacy)

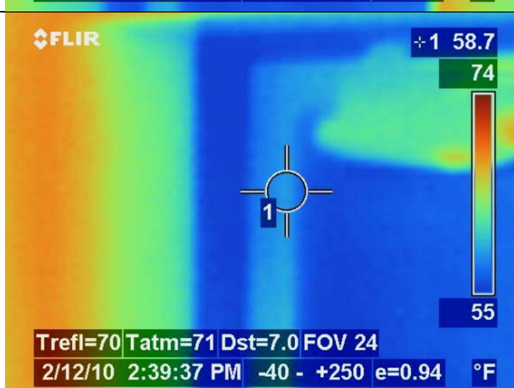


2/12/2010

Front Entrance (Pharmacy)

2/12/2010

Front Entrance (Pharmacy)



2/12/2010

Front Entrance (Pharmacy)

2/12/2010

Room Corner

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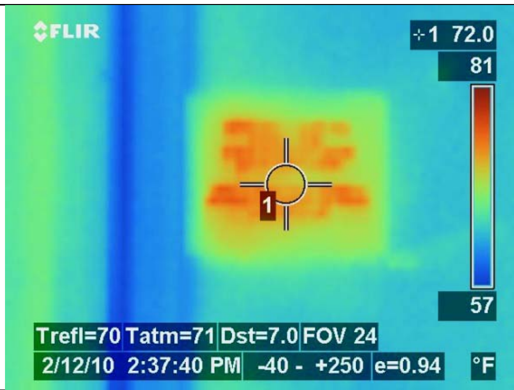
<tr><td>
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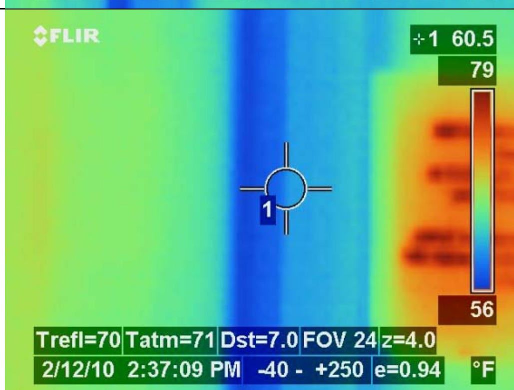
Front Entrance (APW)</td></tr>
<tr><td>
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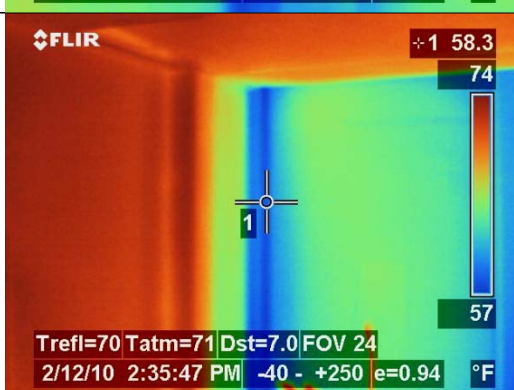
Front Entrance (APW)</td></tr>
<tr><td>
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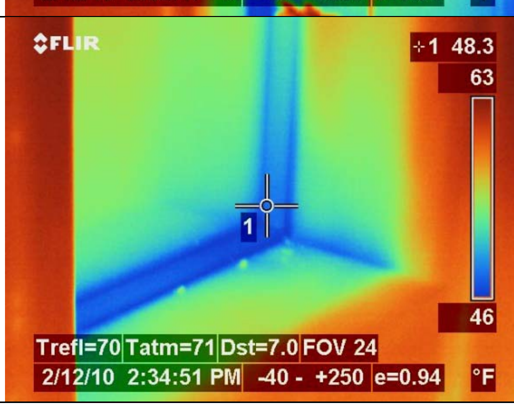
Emergency Exit Window</td></tr>
<tr><td>
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Emergency Exit Window</td></tr>
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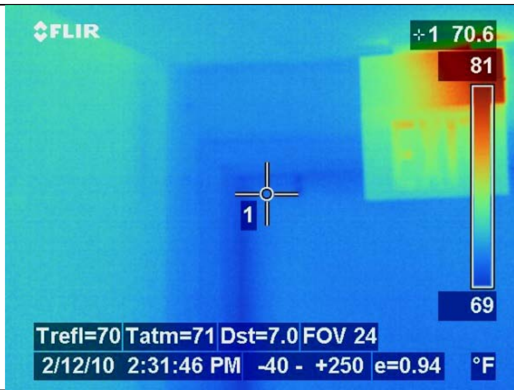
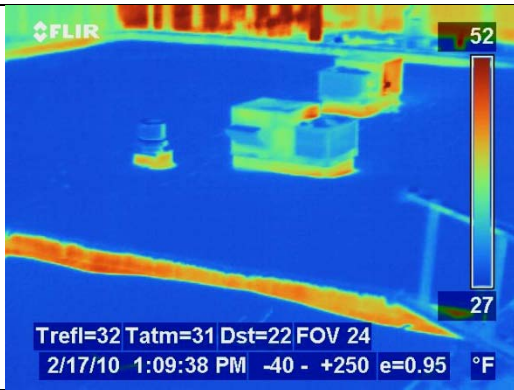
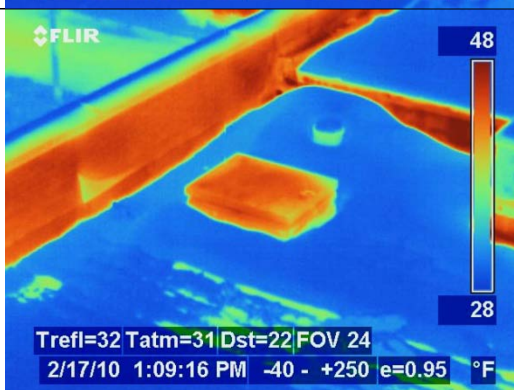
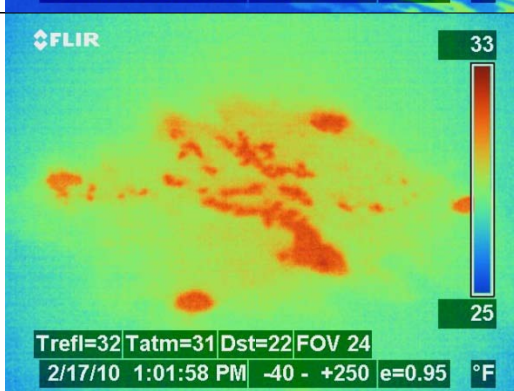
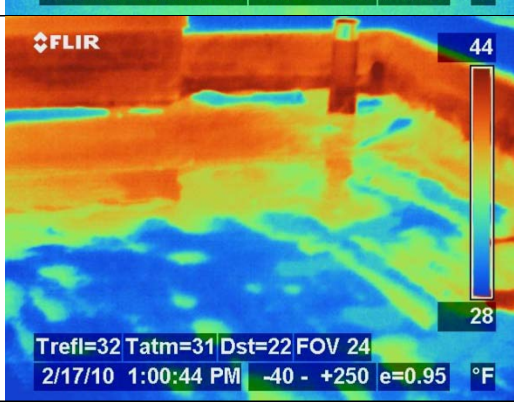
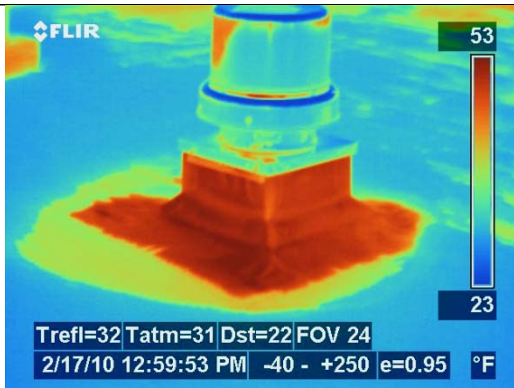
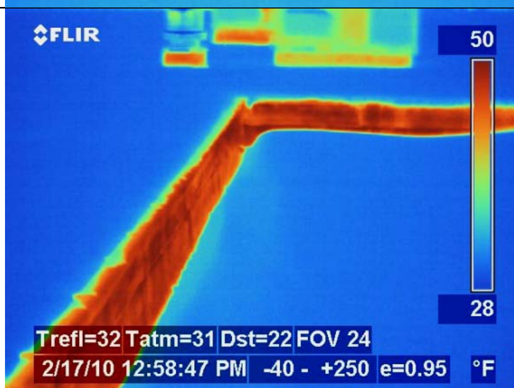
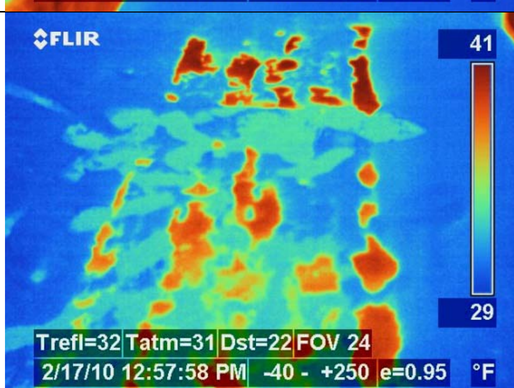
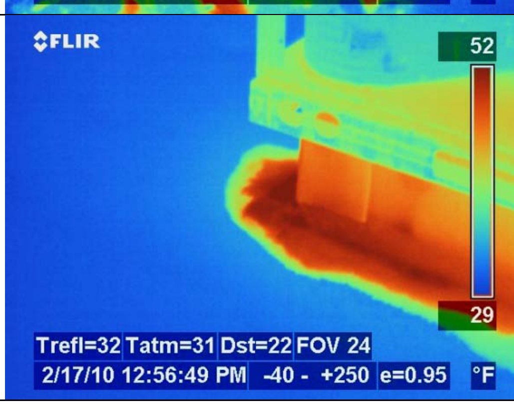
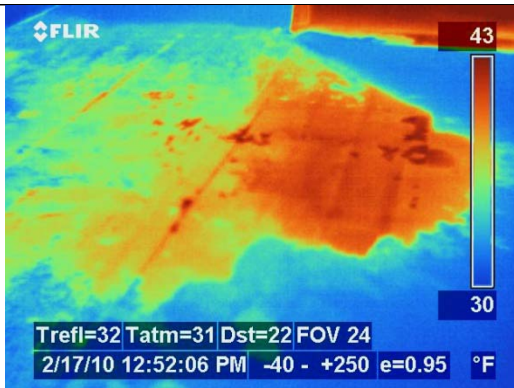
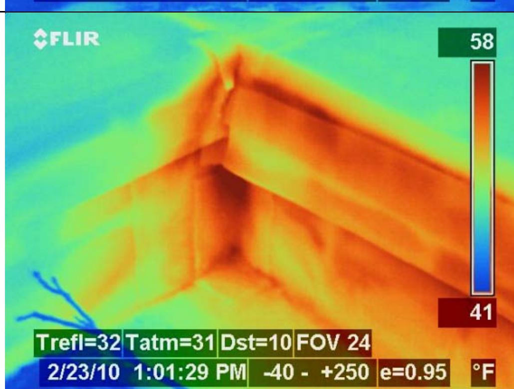
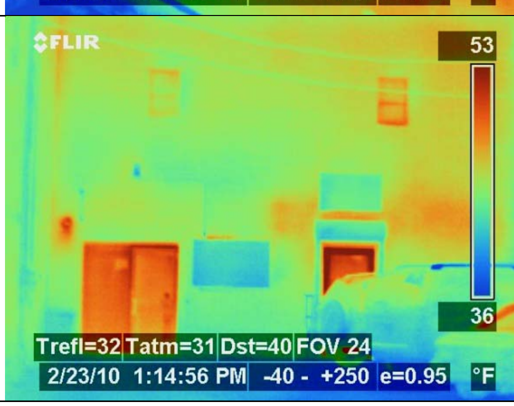
	2/12/2010 Emergency Exit Exterior Door
	2/12/2010 Emergency Exit Exterior Door
	2/12/2010 Emergency Exit Exterior Door
	2/12/2010 Emergency Exit Exterior Door

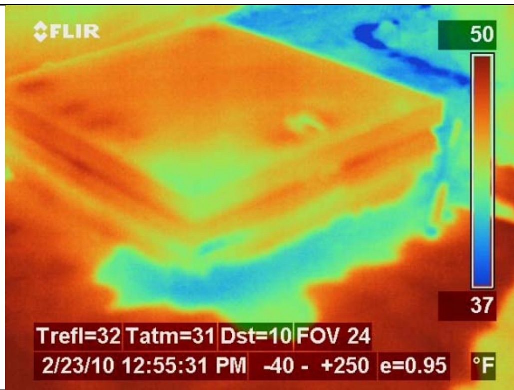
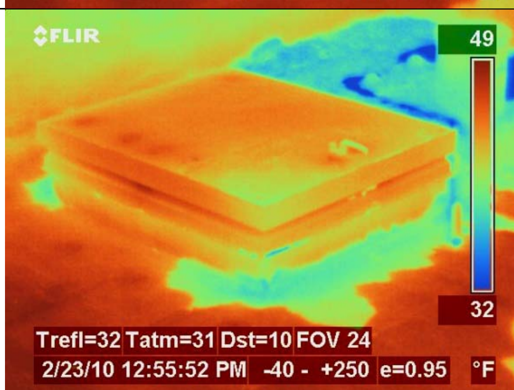
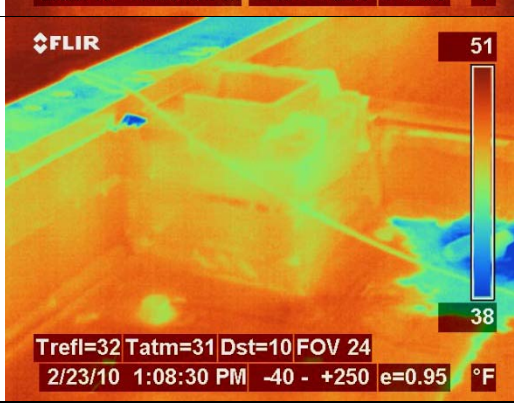
	2/12/2010 Emergency Exit Interior Door
	2/12/2010 Room Corner
	2/12/2010 Room Corner
	2/12/2010 Room Corner

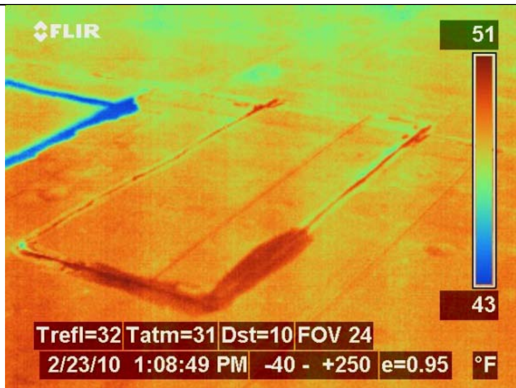
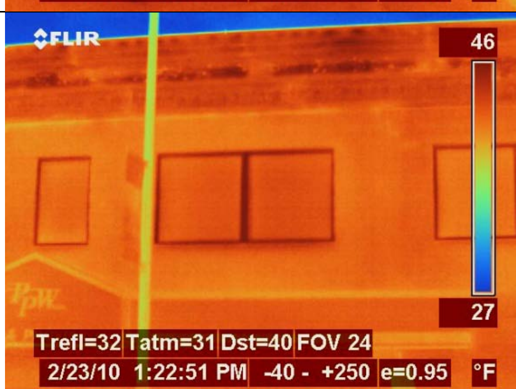
	2/17/2010 Roof with Snow
	2/17/2010 Roof Hatch APW Side with Snow
	2/17/2010 Roof Leak Snow/Slush
	2/17/2010 Roof Corner

	2/17/2010 Roof Exhaust Vent
	2/17/2010 Roof 1ft Vertical Drop
	2/17/2010 Roof with Snow/Slush
	2/17/2010 HVAC Corner

	2/17/2010 Roof with Snow/Slush
	2/17/2010 APW Front Entrance from Outside
	2/23/2010 Roof 1ft Drop Corner
	2/23/2010 APW Front Entrance from Outside

	2/23/2010 APW Front Entrance from Outside
	2/23/2010 APW Front Entrance from Outside
	2/23/2010 APW Front Entrance from Outside
	2/23/2010 APW Hallway Window Near Room 302 from Outside

	2/23/2010 APW Side Roof Hatch
	2/23/2010 APW Side Roof Hatch
	2/23/2010 Roof 1ft Drop No Snow
	2/23/2010 Roof Chimney No Snow

	2/23/2010 Roof Hot Spot No Snow
	2/23/2010 Roof Hot Spot No Snow
	2/23/2010 Office Windows From Green Street
	2/23/2010 Office Windows From Green Street

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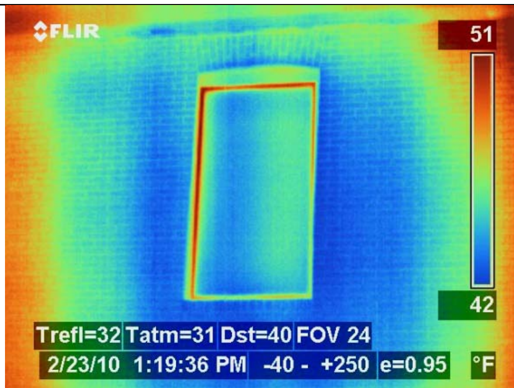
<tr><td>
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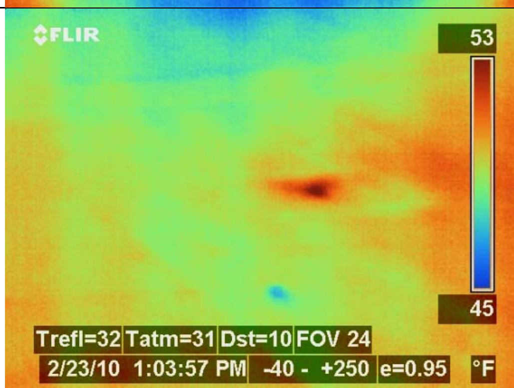
Office Windows From Plymouth Street</td></tr>
<tr><td>
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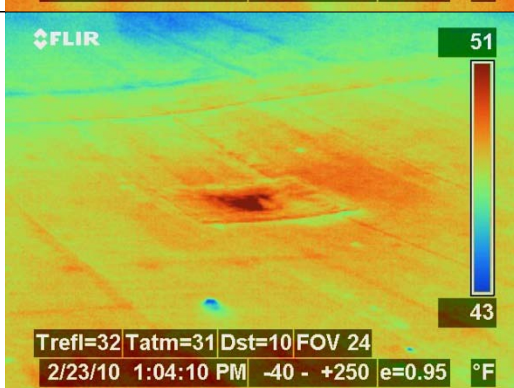
Roof Drain</td></tr>
<tr><td>
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Roof Drain</td></tr>
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Roof Exhaust Vent</td></tr>
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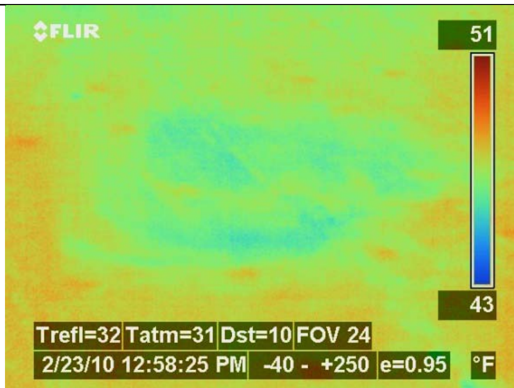
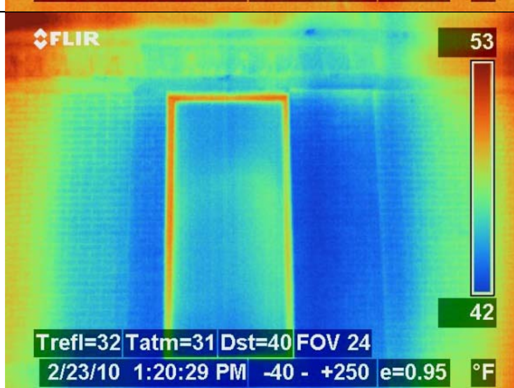
	2/23/2010 Roof No Snow
	2/23/2010 Roof No Snow
	2/23/2010 Office Windows From Plymouth Street
	2/23/2010 Roof Plumbing Vent

Appendix: D

Sunlight Solar

Sunlight Solar Report

Renewable Energy Credit

SUNLIGHT SOLAR energy inc.

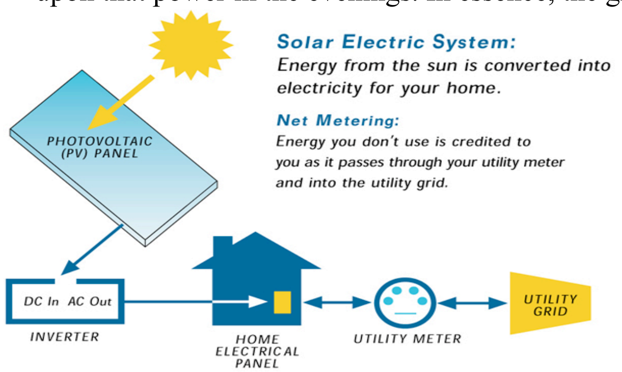
Make the Connection.
Power the Future.

A personalized quote for:			*Prepared By:*		
Bafaro			Jonathan Olinto		
			Sunlight Solar		
			73 Lexingotn St		
			Newton	MA	02464
85 Green Street			Ph:	617.332.1870	
			Cell:	617.610.5645	
Worcester	MA	1604	Email:	jonathan.olinto@sunlightsolar.com	

Today's Date
2/24/10

How Solar Works

Solar Panels (Photovolatic cells) convert the sunlight into electricity. The cells are grouped together to create solar panels. A series of panels are linked together to create an array. The panels are mounted to your roof with a racking system which makes sure your panels stay in place during high winds or heavy snow loads. The inverter takes DC power (solar panels generate DC power) and converts it into AC or household power for running appliances, TVs, computers, etc. The electric panel distributes the electricty throughout your home's wiring and outlets. The utility grid is basically your local utility department. It allows you to store excess electricity on it during the day,then draw upon that power in the evenings. In essence, the grid is like a 100% efficient battery backup.



Rebates and Incentives

Starting in 2008, **Commonwealth Solar** has $68 million available for funding over the next four years to support PV installations in Massachusetts. The effort combines $40 million from the Renewable Energy Trust (Trust) and $28 million from the Alternative Compliance Payment funds that the Massachusetts Division of Energy Resources has collected under the state’s Renewable Portfolio Standard program. The state estimates that Commonwealth Solar will result in 22 megawatts (MW) of PV projects over the next four years.

The Investment Tax Credit (ITC) is a reduction in the overall tax liability for individuals or businesses that make investments in a variety of pre-determined areas. For solar-electric and solar water heating residential property expenditures, the credit is 30 percent of the cost. As of 1/1/09, the ITC has been extended for an additional 8 years. It is a true, un-capped 30-percent tax credit for both residential and commercial solar installations. The ITC tax credit would be realized when you file your tax returns.

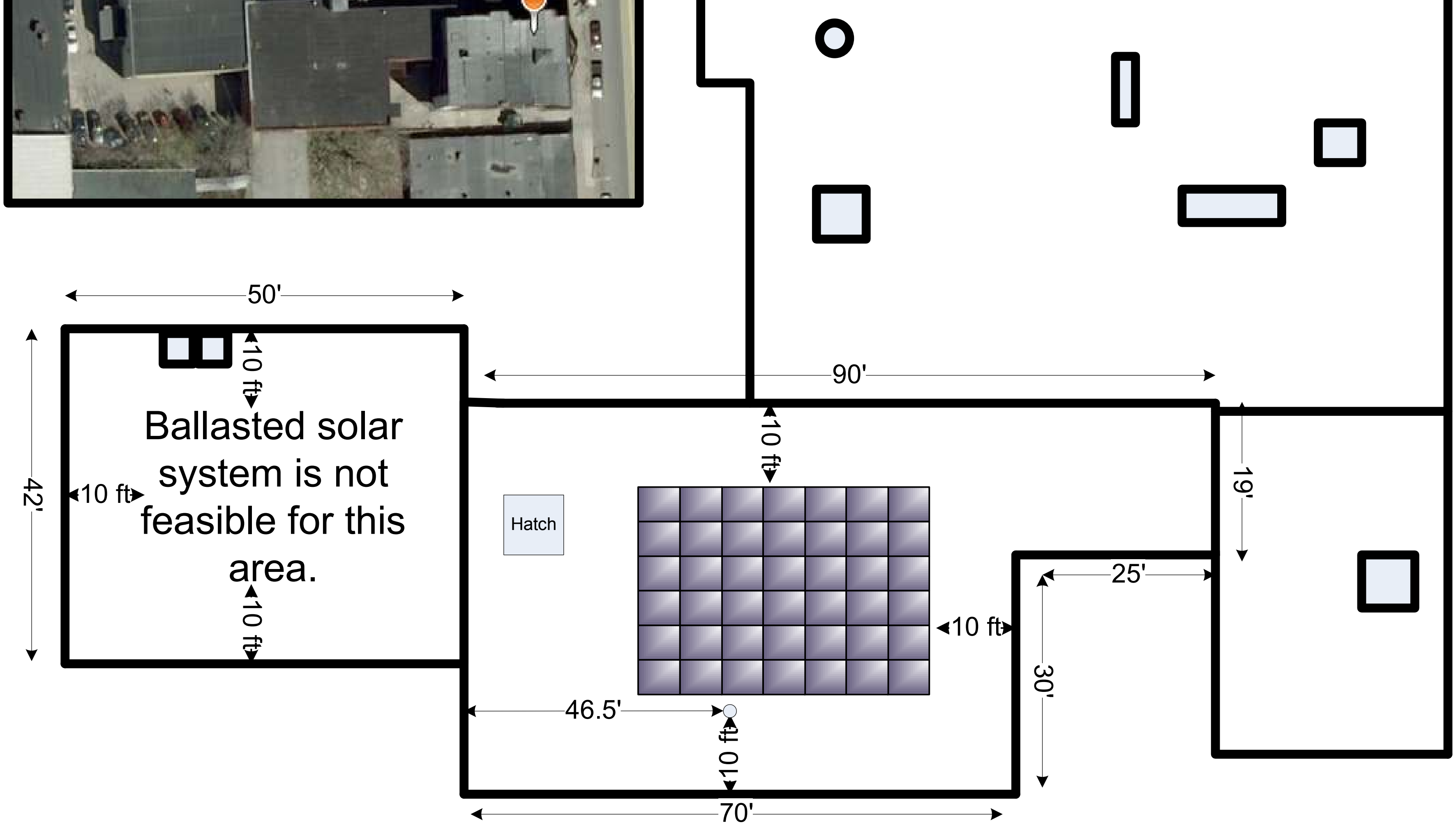
* Please contact your CPA or financial advisor to determine your eligibility for the ITC tax credit and how this and other incentives will apply to you. *

More information at: www.masstech.org

ARRAY DESIGN / SITE DIAGRAM

VIEW	PANEL ORIENTATION (TRUE)	ROOF PITCH (DEGREES)
AERIAL - OVERHEAD	180	0

Sunpower racking: T-5
Modules: SPR-305
# of panels: 42



Sunlight Solar Energy, Inc.
73 Lexington Street, Ma, 02466
Office 617-332-1870
Fax 617-332-1984
www.sunlightsolar.com
HIC # 152314

Aids Project
85 Green Street,
Worcester, MA, 01604

Date: 2/24/10

Drawn By: MLB

Revision #: 1

Sheet #: 1

SUNLIGHT SOLAR energy inc.

Make the Connection.
Power the Future.

73 Lexington Street
Newton, MA 02466
Phone (617) 332-1870
Fax (617) 332-1984
www.sunlightsolar.com

Dear: Bafaro
WPI Project

Thank you for considering Solar Energy and Sunlight Solar Energy, Inc. (SSE), a leading New England and National PV installer.

Below is our comprehensive preliminary quote based on the information you provided in the Customer Self Survey Form. Our quotes are for the complete professional turn-key installation of your PV system. Additionally, we provide a comprehensive PV booklet with schematics, operating manuals and warranties.

Due to changes determined by an onsite evaluation, preliminary rebate estimates may vary from FINAL proposals as much as 5% due to inaccurate information provided in Customer Self Suvey forms.

Material Details:	**System 1**	**System 2**
Solar Panel Manufacturer	SPR 315	Evergreen 210
Solar Panel Model	315	210
Total Number of SunPower Solar Panels (high efficiency panels = less panels)	42	65
Total Solar Panel Wattage (STC)	13,230	13,650
Inverter Model	PVI 15 kW	PVI 15 kW

System Cost Details:		
Total System Cost (post tax)	$81,612	$80,906
Rebate	$19,845	$20,475
Final Cost to You after Rebate	**$61,767**	**$60,431**

Total Estimated Yearly Solar kWh Produced	16,323	16,841
Estimated Percentage of Electric Provided by Solar	12%	12%

Investment and Environmental:		
First Year Estimated Electric Savings in Dollars	$816	$758
First Year Estimated Average Monthly Electricity Saving in Dollars	$68	$63
Federal Tax Credit	$24,483	$24,272
Calc)	$25,300	$25,081
Estimated 25 Year Modified Internal Rate of Return	24%	15%

Our Materials and Labor include:

Massachusetts Industry Leading Ten Year Labor Warranty

Inverter Warranty for 10 Years
Panel Warranty for 25 Years
Proper Solar Panel to Inverter Design to Ensure Efficiency in High Heat and Over Time
No Exposed Roof Penetrations, High Quality Flashing Roof Penetration Flashing System
High Quality Stainless Steel and Aluminum Racking System
We Have Our Own Massachsuetts Crew and Specialize Exclusively in Grid Tied Installations

SSE is one of the leading photovoltaic design and installation corporations in the U.S. and the **leading Solar installer** in Massachusetts. We work under the listed State PV Programs and have installed systems for homes, schools and large commercial entities.

. Licensed Bonded and Insured Massachusetts General Contractor
. Licensed CT PV-1 & PV-2 Installers
. National Licensed NABCEP Installer
. Member SEBANE, SEIA, and ASES
. Connecticut Clean Energy Fund Approved Contractor
. NY State Research and Development Authority Listed Contractor
. Rhode Island Renewable Energy Fund. Winner RIREF Schools Bid
. Massachusetts Technology Collaborative. Winner Large Renewable Program

. EnergyTrust of Oregon Approved Trade Ally

Please call us if you have any questions or would like to schedule an on-site survey.

THANK YOU from the SSE Team!
Attachments

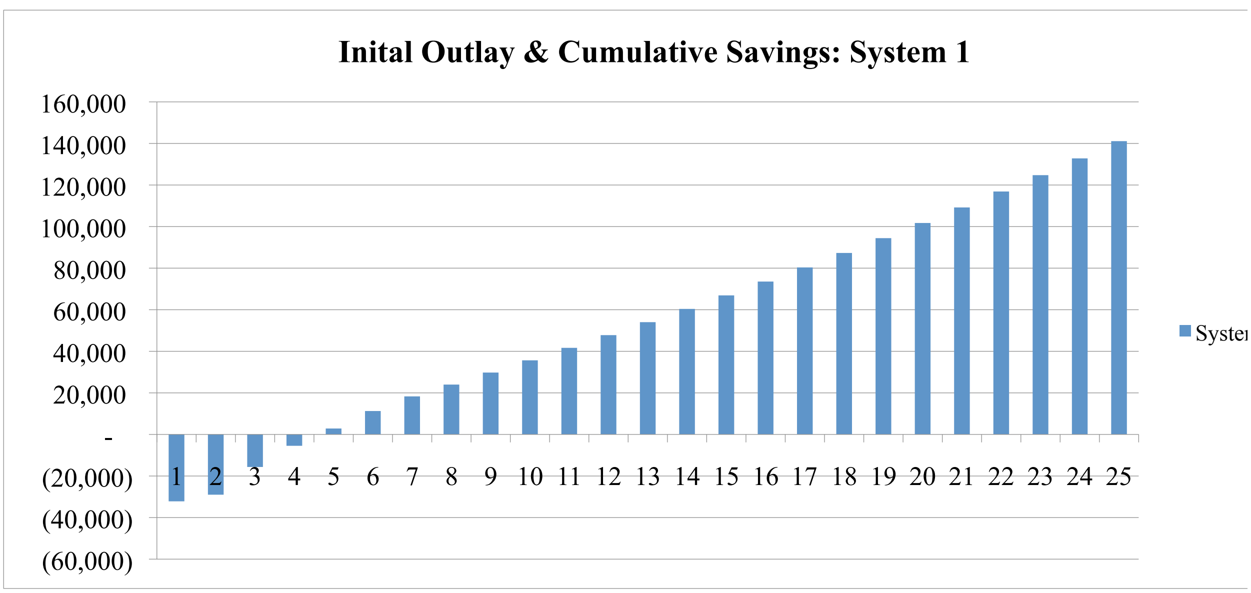
We can beat any competitors price for a comparable system!

73 Lexington Street, Newton, MA 02466 * phone (617) 332-1870, fax (617) 332-1984

Make the Connection.
Power the Future.

Financial Overview	
Year One Savings	$ 32,178.96
Year Two Savings	$ (3,188.57)
Year Three Savings	$ (13,342.98)
Year Four Savings	$ (10,182.31)
Year Five Savings	$ (8,321.34)
Year Six Savings	$ (8,407.91)
Total Savings After Six Years	**$ (11,264.15)**
Yearly Savings After Year Six	**$ (4,586)**

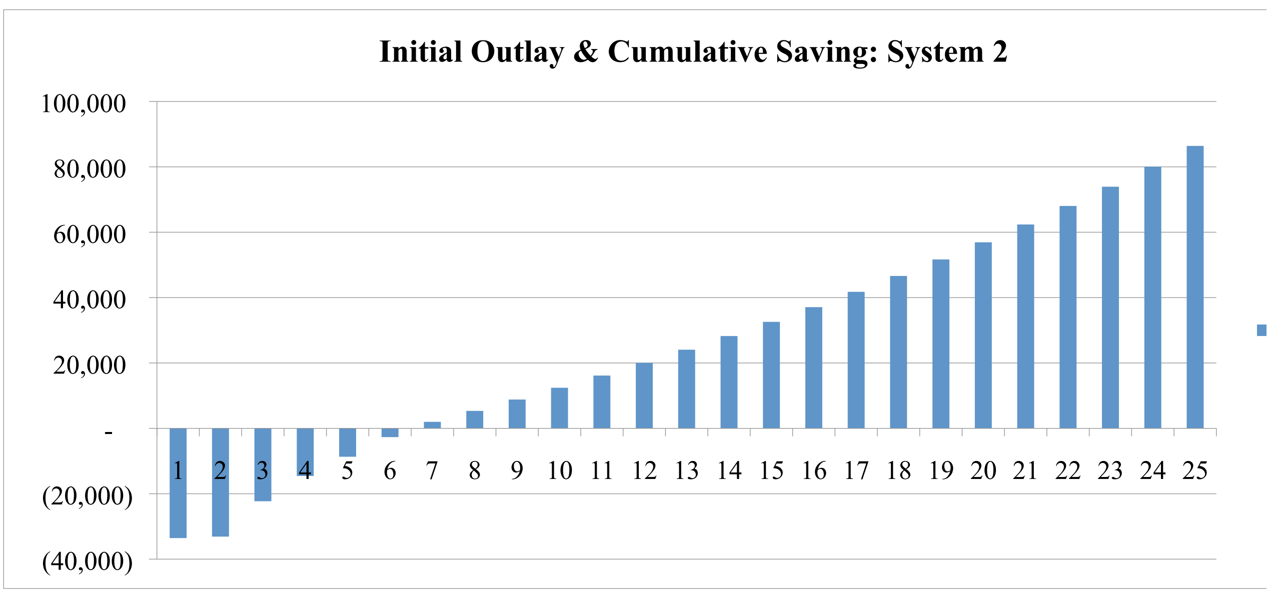
The following graph demonstrates the intial cost of the system being offset and then the cumulative savings from tax credits and energy.



m 1

Financial Overview	
Year One Savings	$ 33,552.17
Year Two Savings	$ (447.51)
Year Three Savings	$ (10,822.77)
Year Four Savings	$ (7,713.50)
Year Five Savings	$ (5,892.70)
Year Six Savings	$ (6,002.61)
Total Savings After Six Years	**$ 2,673.09**
Yearly Savings After Year Six	**$ (4,731)**

The following graph demonstrates the intial cost of the system being offset and then the cumulative savings from tax credits and energy.



System 2

Purchase/Sale/Lease	
System 1	
Purchase Price	81,612
Rebate	19,845
Out of pocket	61,767
ITC- Federal 30%	24,483

Breakeven

	Basis	depr-1	depr-2	depr-3
Depreciation on investment (federal)	69,370	13,874	22,198	13,319
Federal Tax Savings		(4,162)	(6,660)	(3,996)
Depreciation on investment (State)	81,612	16,322	26,116	15,669
State Tax Savings		(897.73)	(1,436.36)	(861.82)

depr-4	depr-5	depr-6	total
7,991	7,991	3,996	69,370
(2,397)	(2,397)	(1,199)	(20,811)
9,402	9,402	4,701	81,612
(517.09)	(517.09)	(258.55)	(4,488.64)

Purchase/Sale/Lease	
System 2	
Purchase Price	80,906
Rebate	20,475
Out of pocket	60,431
ITC- Federal 30%	24,272

	Basis	depr-1	depr-2	depr-3
Depreciation on investment (federal)	68,770	13,754	22,006	13,204
Federal Tax Savings		(4,126)	(6,602)	(3,961)
Depreciation on investment (State)	80,906	16,181	25,890	15,534
State Tax Savings		(889.97)	(1,423.95)	(854.37)

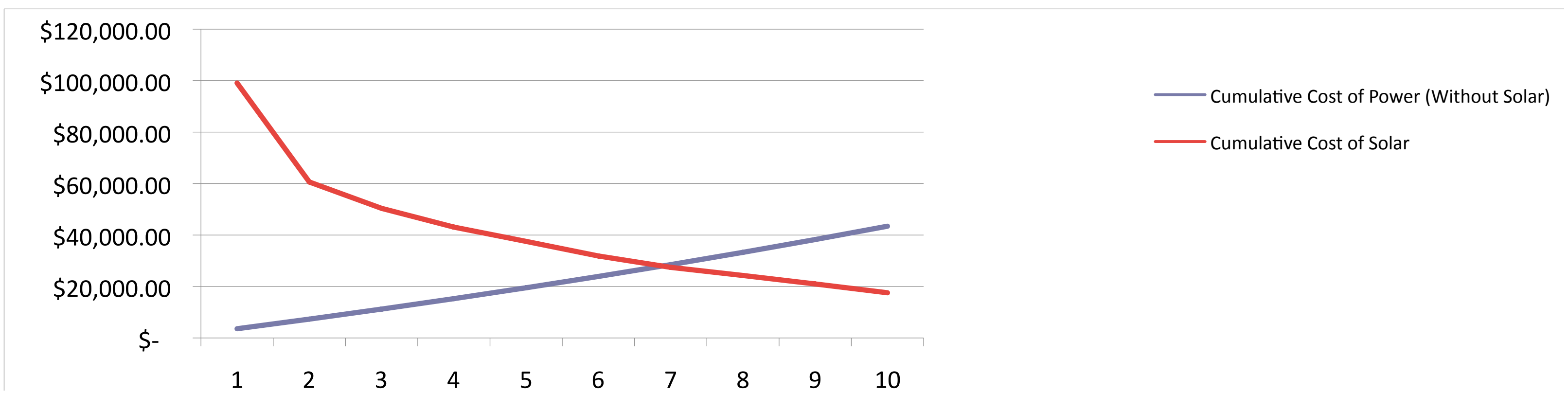
depr-4	depr-5	depr-6	total
7,922	7,922	3,961	68,770
(2,377)	(2,377)	(1,188)	(20,631)
9,320	9,320	4,660	80,906
(512.62)	(512.62)	(256.31)	(4,449.83)

Sunlight Solar Energy Inc

Financial Site Analysis for Solar Energy

Developed for: **0**

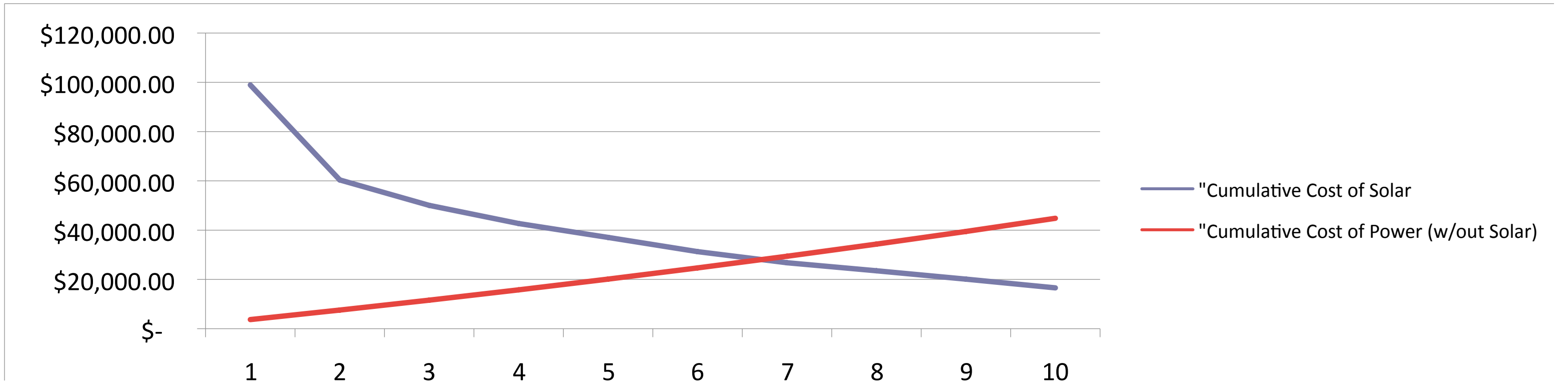
Age	Year	Energy Savings Yearly	State and Federal Tax Penalty on Energy Savings	ITC (30% Federal Tax Credit)	Federal Depreciation Tax Savings	State Depreciation Tax Savings after Fed tax effects	State cash incentive program	State and Federal Tax Penalty on ETO Cash Incentive	Cost of System to Install	Yearly Cash Flow
0	2010	$ (3,591)	$ 1,216				$ 19,845		$ 81,612	$ 99,081
1	2011	$ (3,740)	$ 1,266	$ (24,483)	$ (4,162)	$ (628)		$ (6,718)		$ (38,466)
2	2012	$ (3,896)	$ 1,319		$ (6,660)	$ (1,005)				$ (10,242)
3	2013	$ (4,058)	$ 1,374		$ (3,996)	$ (603)				$ (7,283)
4	2014	$ (4,227)	$ 1,431		$ (2,397)	$ (362)				$ (5,556)
5	2015	$ (4,403)	$ 1,490		$ (2,397)	$ (362)				$ (5,672)
6	2016	$ (4,586)	$ 1,552		$ (1,199)	$ (181)				$ (4,413)
7	2017	$ (4,777)	$ 1,617							$ (3,160)
8	2018	$ (4,975)	$ 1,684							$ (3,291)
9	2019	$ (5,182)	$ 1,754							$ (3,428)
		$ (43,436)	**$ 14,703**	**$ (24,483)**	**$ (20,811)**	**$ (3,142)**	**$ 19,845**	**$ (6,718)**	**$ 81,612**	**$ 17,570**



Financial Site Analysis for Solar Energy

Developed for: **0**

Age	Year	Energy Savings Yearly	State and Federal Tax Penalty on Energy Savings	ITC (30% Federal Tax Credit)	Federal Depreciation Tax Savings	State Depreciation Tax Savings after Fed tax effects	State cash incentive program	State and Federal Tax Penalty on ETO Cash Incentive	Cost of System to Install	Yearly Cash Flow
0	2010	$ (3,705)	$ 1,254				$ 20,475		$ 80,906	$ 98,930
1	2011	$ (3,859)	$ 1,306	$ (24,272)	$ (4,162)	$ (628)		$ (6,931)		$ (38,546)
2	2012	$ (4,020)	$ 1,361		$ (6,660)	$ (1,005)				$ (10,324)
3	2013	$ (4,187)	$ 1,417		$ (3,996)	$ (603)				$ (7,369)
4	2014	$ (4,361)	$ 1,476		$ (2,397)	$ (362)				$ (5,644)
5	2015	$ (4,543)	$ 1,538		$ (2,397)	$ (362)				$ (5,764)
6	2016	$ (4,732)	$ 1,602		$ (1,199)	$ (181)				$ (4,510)
7	2017	$ (4,928)	$ 1,668							$ (3,260)
8	2018	$ (5,133)	$ 1,738							$ (3,396)
9	2019	$ (5,347)	$ 1,810							$ (3,537)
		$ (44,815)	**$ 15,170**	**$ (24,272)**	**$ (20,811)**	**$ (3,142)**	**$ 20,475**	**$ (6,931)**	**$ 80,906**	**$ 16,580**



SUNLIGHT SOLAR energy inc.

Make the Connection.
Power the Future.

Today's Date	February 24, 2010
Estimate Valid To:	March 26, 2010
Sales Contact	Jonathan Olinto
CPA Type	Preliminary Proposal

CUSTOMER INFORMATION

Company Name	WPI Project				
	Bafaro				
Customer Address	85 Green Street				
City, State and Zip	0	MA	00000		
Installation Address	85 Green Street				
City, State and Zip	0	MA	00000		
Contact Numbers	203-564-0077	0	Bafaro	patdh1028@wpi.edu	
	Office	Cell	Owner	E-mail	

MATERIAL DETAIL

	Manufacturer	Model	Number of Panels & Inverters		Total Watts
Solar Panels*	SPR 315	315	42		13,230
Inverter**		Solectria	PVI 15 kW		1
Racks	SunPower	T5		Rack Type	Self Ballasted

*Listed to UL Standards, Sunpower 25-year warranty. **Listed to UL Standards, Sunpower 10-year warranty.

REBATE CALCULATIONS

Rebate*	$19,845.00

*100% of rebate is passed on to customer.

SOLAR RESOURCE INFORMATION

Resource Fraction	96.00%

ESTIMATED SOLAR CONTRIBUTION*

Month	Monthly Home Electricity Usage in kilowatt hours	Monthly Solar Production in kilowatt hours, adjusted for all factors *, **	Percent of Home's Electrical Use Provided by Solar System	Current Dollar Value of Monthly Solar Production***	Total of Current Monthly Solar $ amount added to current Renewable Energy Credit $ amount
January	11,525	1,107	10%	$243	$315
February	12,273	1,268	10%	$279	$361
March	12,482	1,512	12%	$333	$431
April	10,385	1,592	15%	$350	$454
May	10,460	1,578	15%	$347	$450
June	12,972	1,619	12%	$356	$461
July	15,058	1,619	11%	$356	$461
August	10,875	1,578	15%	$347	$450
September	10,482	1,430	14%	$315	$408
October	10,494	1,241	12%	$273	$354
November	10,875	904	8%	$199	$258
December	11,565	877	8%	$193	$250
Yearly or Totals* **	**139,446**	**16,325**	**12%**	$3,591	$4,653

*Solar energy production will be logged using a utility grade meter installed on the output of the inverter or via the internet.
** Yearly and monthly total energy production estimates can vary between 10-20% due to seasonal weather conditions.
*** This amount does not include any money you may receive from selling your Rewnewable Energy Credits "REC's" or "Green Tags"(Please see attached Investment Sheet for estimated REC's).

PRICE INFORMATION

Solar Panels	$51,333.46
Inverter(s)	$8,096.76
Balance of Systems: racks, solar meter and base, wire, conduit, fusing, breakers, disconnects	$5,343.86
Labor	$13,683.52
Shipping	$1,376.45
Permits and Interconnection	$1,133.55
Additional Costs	$644.00
Taxes	$0.00
TOTAL INSTALLED PRICE (post-tax)	$81,611.60
MINUS REBATE	$19,845.00

"The rebate amount is an <u>estimate</u> only and is not valid until the Massachusetts Technology Collaborative final letter.

CUSTOMER PAYMENT SCHEDULE

Estimated Installation State Date:			May 25, 2010
CUSTOMER INVESTMENT			**$61,766.60**
Paid As Follows			
20% Upon Acceptance of this Agreement.*	Initial Here		$12,353.32
50% Upon Delivery of Materials.	Initial Here		$30,883.30
20% Upon Completion of Installation of Materials.	Initial Here		$12,353.32
10% Upon Utility Inspection	Initial Here		$6,176.66

Final MTC rebate (40%) held until final commissioning of system. 10% held for 6 months after commissioning.

OTHER PROVISIONS

Roof Attachment: Sunlight Solar Energy, herein refered to as SSE, will install and properly detail all solar roof penetrations and attachments so as not to invalidate the roof warranty. Only solar roof penetrations are covered. Properly sealed, SSE, Inc. will be held harmless for leakage.

Rebate. SSE will guarantee the rebate amount as quoted by MTC.

SW Adder: "Customer" receive all rights to the SW MA adder. SSE, Inc. will process and help on all paperwork necessary for its' fulfillment
Federal Incentives: "Customer", is wholly responsible for determining the amount of Federal Tax Credit (ITC) and/or Depreciation allowances that are available and useable. SSE, Inc. does not guarantee the
Utility Interconnection Agreement. The interconnection agreement is a contract between the Customer and the NSTAR Electric Company, herein refered to as NSTAR. SSE, Inc. will coordinate, submit and pay
MTC/Massachusetts Technology Collaborative, herein refered to as MTC, Financial Assistance Agreement, herein refered to as FAA. The FAA is an agreement between MTC and the Customer. SSE, Inc.
uuuuu
Right to Inspect System: Customer will allow MTC and/or authorized representatives to make a reasonable number of site inspections during and after installation of the solar electric system up to 12 months
Publicity: Customer will work with MTC should they prepare press releases or any news conferences related to the photovoltaic system. Any visible signage, kick off meetings, press releases or other requirements of MTC will be at Customer's expense.
Other: Neither MTC or the State of Massachusetts; (1) endorses the workmanship of any Eligible installer; nor (2) guaranty, warrantees, or in any way represents or assumes liability for any work proposed or carried
Other: The MTC will not make any rebate payments without proof that all required permits and approvals have been obtained. Customer is not liable for the rebate to the contractor.
Warranty: SSE, Inc. has a ten year 100% labor warranty.

SIGNATURES

Customer		Date:
Sunlight Solar Energy, Inc. CCB#158922		Date:



EPA's Green Power Partnership

Renewable Energy Certificates

U.S. Environmental Protection Agency
1200 Pennsylvania Ave, NW (Mail Code 6202J)
Washington, DC 20460
www.epa.gov/greenpower

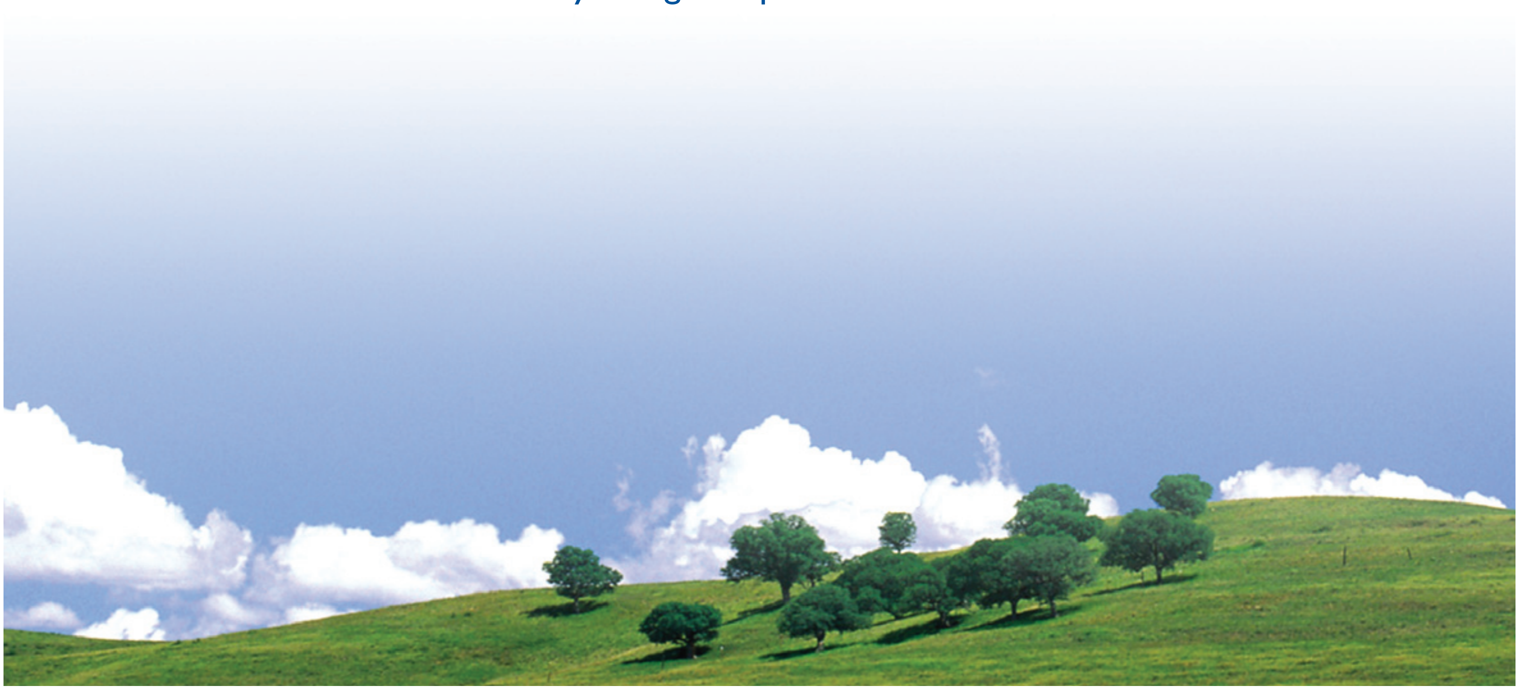
EPA GREEN POWER PARTNERSHIP®

Last updated: July 2008

Many people and organizations are willing to pay for electricity that is produced on their behalf using cleaner, renewable sources of generation. These buyers often find renewable electricity attractive for its environmental and greenhouse gas reduction benefits when compared to conventional fossil fuel-based electricity generation.

Both individual and organizational buyers have several green power product options available. These include buying renewable energy certificates (RECs) by themselves, buying RECs along with physical electricity from their utility service provider, or developing onsite renewable projects that produce both electricity and RECs together. RECs in particular have become an important choice for buyers of green power nationwide and serve as the "currency" for renewable energy markets.

This document provides a review of RECs: what they are, how they work, and why they are an important option for individual and organizational buyers in renewable electricity and green power markets.



EPA's Green Power Partnership

Renewable Energy Certificates

What Are RECs?

RECs represent the environmental and other non-power attributes of renewable electricity generation and are a component of all renewable electricity products. RECs are measured in single megawatt-hour increments and are created at the point of electric generation. Buyers can select RECs based on the generation resource (e.g., wind, solar, geothermal), when the generation occurred, as well as the location of the renewable generator.

RECs provide key information about the generation of renewable electricity delivered to the utility grid. Since RECs represent only the environmental or non-power attributes of renewable electricity generation, they are not subject to electricity delivery constraints. The information conveyed by a REC allows buyers to make specific environmental claims about how their electricity is produced. RECs usually include the following primary attributes and information:

- The type of renewable resource producing the electricity
- The vintage of the REC (i.e., the date when it was created)
- The vintage of the renewable generator, or the date when the generator was built
- The renewable generator's location
- The RECs eligibility for certification or renewable portfolio compliance
- The renewable generation's associated greenhouse gas emissions (if any)

RECs are increasingly seen as the "currency" of renewable electricity and green power markets. They can be bought and sold between multiple parties, and they allow their owners to claim that renewable electricity was produced to meet the electricity demand they create.

A REC represents and conveys the environmental and other non-power attributes of one megawatt-hour of renewable electricity generation.

Increasingly, federal, state and local governments are also using RECs as a credible means to meet environmental goals for renewable energy generation. For example, most states allow utilities to use RECs to meet mandated state renewable portfolio standards. State renewable portfolio standards require that a percentage of a utility's electricity generation comes from renewable resources. Increasingly, individuals and organizations are also buying RECs to satisfy a number of other environmental and non-environmental goals:

- Avoid the carbon dioxide (CO_2) emissions associated with conventional electricity use
- Reduce some types of air pollution
- Hedge against future electricity price increases for onsite and some utility products
- Serve as a brand differentiator
- Generate customer, investor, or stakeholder loyalty and employee pride
- Create positive publicity and enhance public image
- Demonstrate civic leadership

How Do RECs Work?

To understand how RECs work, it is helpful to understand how electricity is delivered across the utility grid, as well as what makes renewable electricity generation attractive to individuals and organizational buyers.

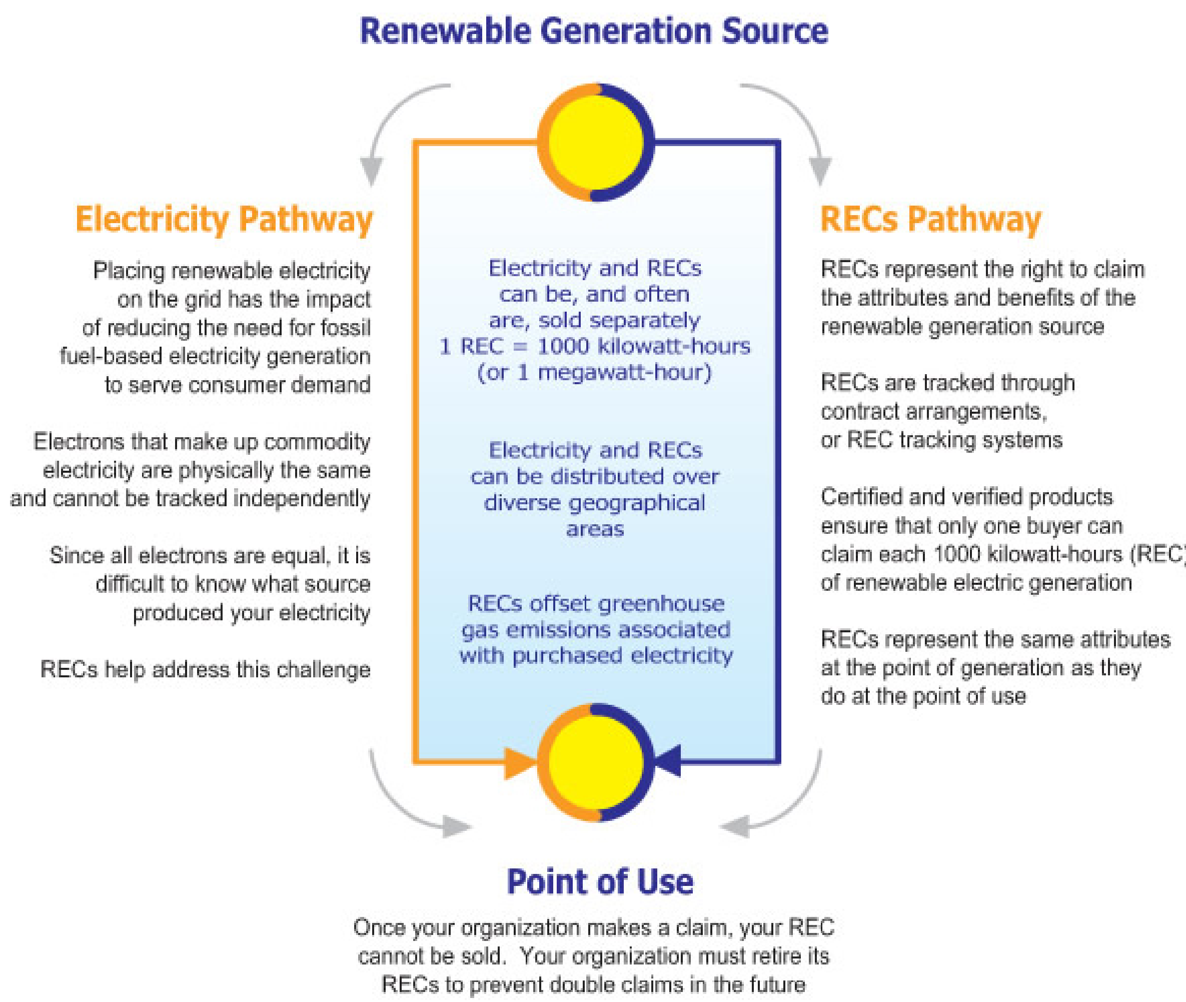
Within the United States, electricity demand is met by various types of generation technologies and fuel resources. These electricity generators feed electrons onto the utility grid for delivery to consumers through a complex network of wires and distribution infrastructure. Because the electrons produced from the different technologies and fuel resources are physically the same, it is impossible for individuals or organizations to know what type of generation technology or resource produced the electricity that reaches their particular facility.

RECs help address the issue that the electricity or electrons a consumer receives from their utility does not identify how the electricity was generated. RECs were created to help convey the attributes of electricity generated from renewable resources to buyers. Analogous to the utility delivering the physical electricity through wires, RECs serve as the means to deliver the environmental and non-power attributes of renewable electricity generation to buyers – separate from the physical electricity. (See Figure 1.) All renewable electricity generation can be viewed as having two separate parts:

1. The commodity electricity or electrons
2. The environmental and other non-power attributes of generation represented by a REC

Because RECs are monitored and verified, individuals and organizational buyers can buy RECs and be confident that electricity generated on their behalf was done so with renewable energy resources.

Figure 1



Why Are RECs an Important Option for Consumers?

Individuals and organizations may find that buying RECs separately from their electricity service is a useful way to tap into green power markets. More than half of U.S. electricity customers have an option to purchase some type of green power product from a retail electricity provider, but the rest do not have that choice. RECs provide buyers the option to select renewable resources to meet their electricity demand.

For example, in states that have restructured electricity markets, consumers can often buy green power products by switching electric service providers if their current provider does not offer a green power product. If consumers do not wish to switch electric service providers they also have the option to buy RECs separately from their existing electricity service. This approach allows buyers to avoid the environmental impacts of their electricity, since the REC represents a specific amount of avoided greenhouse gas emissions.

RECs can also be purchased in situations where a utility green power product is available, but this utility product does not have the desired environmental characteristics, resource base, or price. RECs provide more choices and more competitive prices because they are not constrained by where they are created or by transmission bottlenecks.

Who Owns a REC?

A REC can be bought and sold between buyers and sellers from its generation to its final point of application or use at a facility. Typically, regional tracking systems register RECs in order to keep track of how much renewable electricity was produced.[1] Tracking systems assign each REC a unique number, which matches the REC to its current owner. Alternatively, buyers can use third-party audits to confirm the contractual chain of ownership between multiple parties. REC contracts typically include a statement, or attestation, from the seller that the RECs have not been sold to, and cannot be claimed by, another party.

What Is the Difference between Renewable Electricity and Green Power?

Renewable electricity is produced from resources that do not deplete when their energy is harnessed, such as sunlight, wind, waves, water flow, biological processes such as anaerobic digestion (e.g., landfill gas), and geothermal energy. Renewable electricity resources are distinct from fossil and nuclear fuels, which are also used to generate electricity.

EPA defines green power as a subset of renewable electricity and represents those renewable resources and technologies that provide the highest environmental benefit. Green power is renewable electricity produced from solar, wind, geothermal, biogas, biomass, and low-impact small hydroelectric resources. Definitions for renewable energy can vary and may include resources that are acknowledged or perceived to have environmental impacts, such as land use and fisheries impacts of large hydro dams.

RECs are a credible and easy way to keep track of who can claim the environmental attributes of renewable electricity generation through electronic tracking systems. Because RECs are carefully counted, tracked and associated with an owner, no two buyers can legally claim the same environmental benefits of the renewable electricity generation.

Once a buyer makes an environmental claim based on a REC, the buyer can no longer sell the REC and the REC is considered permanently "retired." Buyers can also have their RECs retired in their name by their supplier to ensure that no other entity can lay claim to the same environmental benefits.

1 Regional tracking systems have been put in place to monitor electricity generation across the United States. A REC is produced for every megawatt-hour of electricity generated from a renewable resource and is assigned a tracking number within the system. The tracking number stays with the REC and is transferred between buyers and sellers until a final owner makes a claim, at which time the REC is considered "retired" in the system.

Consumers or organizations with onsite renewable electricity systems should be clear about who owns the RECs produced by the onsite system. If the onsite system owner wants to make an environmental claim about the use of renewable electricity from the onsite system, they should ensure that they have and retain ownership of the RECs produced by the onsite renewable electricity system. If the onsite system owner uses the system-produced electricity, but sells the RECs to another party, they are no longer using green power and cannot make a claim to be doing so.

Are There Standards for RECs?

There are a number of third-party organizations in the market that certify RECs. As a best practice, EPA recommends that buyers seek out certified products as a form of buyer protection. Certified RECs should meet national standards for resource content and environmental impact. Certification answers the question "Does this product meet accepted standards for quality?"

Who Sells RECs?

RECs and the attributes they represent are an ingredient of all green power products. REC providers—including utilities, REC marketers, and other third-party entities—may sell RECs alone or sell them bundled with electricity. As of 2007, more than 50 percent of utility customers have access to green power bundled products, whereas all customers have access to buying renewable energy certificates.

Buyers can identify green power suppliers using EPA's Green Power Locator tool: www.epa.gov/greenpower/pubs/gplocator.htm

Green Power Product Provider/Source	Geographic Availability	Renewable Energy Certificate	Physical Electricity
REC Marketers	Nationally Available	✓	
Utility Green Pricing Programs	Unrestructured Electricity Markets	✓	✓
Utility Green Marketing Programs	Restructured Electricity Markets	✓	✓
Onsite Renewable Electricity Systems	Any Grid-Connected Point of Use	✓	✓

Appendix: E

Conservation Posters

 http://www.awarenessideas.com/AI-ep248-Save-Energy-Each-Person-Each-Idea-Ma-p/ai-ep248.htm	No comments
 http://www.awarenessideas.com/AI-EP246-Whether-half-full-or-half-empty-resou-p/ai-ep246.htm	**Pro:** • *Love this one, resources are very limited* • *Creative and displays a valuable message* • *YES* • *KOOL* **Con:** • *Ugly*
 http://www.art.com/products/p13593403-sa-i2716603/rethink-consumption.htm	**Pro:** • *I like very much* • *Brings awareness, re: options (check plus) for consumption* • *Love this* **Suggestion:** • *Background should be earth color*

<table>
<tr><td>

http://www.awarenessideas.com/AI-EP244-Keep-the-thermostat-appropriate-to-a-h-p/ai-ep244.htm</td><td>Con:
• Kind of ugly
• I don't understand</td></tr>
<tr><td>

http://www.goodlifer.com/2009/03/earth-hour/</td><td>Pro:
• YES</td></tr>
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http://www.newcastle.gov.uk/core.nsf/a/energyposters</td><td>No comments</td></tr>
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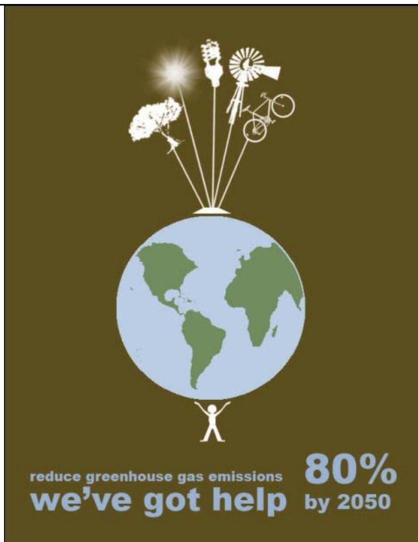
<td>
</td>
<td>Pro:
love this graphic
Con:
Use difficult words, we are plain folks</td>
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<td>

http://www.newcastle.gov.uk/core.nsf/a/energyposters</td>
<td>Con:
To demanding</td>
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http://www.newcastle.gov.uk/core.nsf/a/energyposters</td>
<td>Pro:
KOOL
Good message
Con:
A little boring</td>
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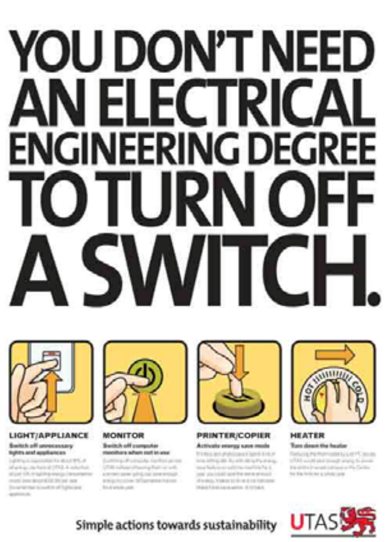
<td>

http://www.staff.utas.edu.au/news/articles/help-utas-save-energy</td>
<td>Pro:

(check plus) like it
Like very much
Its cool, like
YES
</td>
</tr>
<tr>
<td>

http://www.ecofriendlyprinter.com/Promotional-Items-Think-Positive-Think-Green-Posters-25488.Item.html</td>
<td>Pro:

Like
Like
Good, simple
I like the visual I'm all about the green
Makes you think, a lot
</td>
</tr>
<tr>
<td>

http://www.awarenessideas.com/AI-ep304-If-not-now-when-If-not-you-who-Con-p/ai-ep304.htm</td>
<td>Pro:

Like
Like this one, pretty cool
Like this one a lot
Makes one think, very good
I like it
Good message

Con:

Ugly graphic
</td>
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<td>Pro:

Nice
Like it very much. I get it, don't get the flower
</td>
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http://www.awarenessideas.com/AI-EP107-Control-Gas-Use-Stop-Energy-Waste-En-p/ai-ep107.htm</td>
<td>No comments</td>
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http://www.awarenessideas.com/AI-EP101-For-the-sake-of-all-children-please-sa-p/ai-ep101.htm</td>
<td>Pro:

Children are our future, let's keep the world clean!!!
I like, cool
I like it, pretty cool

Con:</td>
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http://www.awarenessideas.com/AI-ep102-Conserve-Its-in-your-hands-Energy-C-p/ai-ep102.htm

Pro:

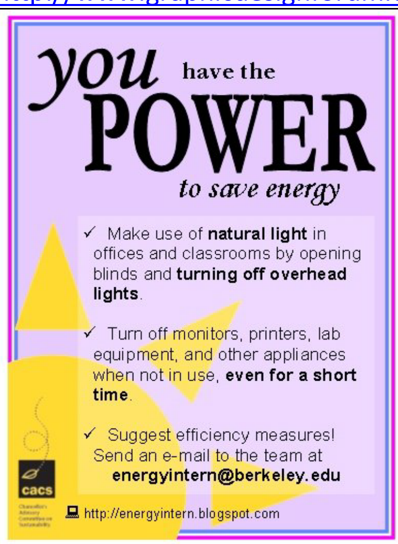
- *Message is nice, like the colors also*

http://www.graphicdesignforum.com/forum/showthread.php?t=39511

Pro:

- *Like this one because it gives suggestions*
- *Love, love, love this!!!*

Con:



Pro:

- *Like the tag line*

Con:

- Too busy
- Too busy, too wordy