OPTIMIZING ENERGY AUDITS FOR K-12 EDUCATIONAL FACILITIES

by

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A REPORT

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Abstract

Conserving energy and minimizing utility consumption are primary focuses in educational facilities because annual budgets are often limited. Consequently, building energy audits are an effective tool to assist in evaluating existing buildings and identify methods of reducing annual energy use. Therefore, this report describes what building energy audits are, how they can be performed, and how to discover energy saving measures from the results. Specifically, the research considers physical building features and building operations and evaluates them for possible modification to reduce energy use. Proposed solutions vary from no-to-low cost options to larger capital investments. The research also analyzes building components for economic viability using the net present cost and payback period as the basis of comparison, permitting recommendations. The audit procedure and the economic analyses are presented in a manner that allows individual educational facility managers to assess their own buildings.

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Also, I would like to thank Susie English, Principal of John Paul II Catholic Elementary School, for allowing me to conduct an energy audit case study at her school.

Dedication

I would like to dedicate this Master's Report to my parents, for their undivided support and interest throughout my college career. They have continually guided and encouraged me to be the best person and student that I could possibly be.

Chapter 1 - Introduction

Building energy audits began as rudimentary energy conservation tools to bring light to apparent energy-wasting habits and procedures. Today, they have evolved into detailed reports and analyses that can provide detailed recommendations to building owners. Nowadays, this analysis of energy use and consumption is a vital component of the increased concentration to conserve energy. In pursuit of that goal, the research presented in this report aids in reducing energy use within K-12 educational facilities. The objective is to reduce operational energy costs by implementing building upgrades and improvements that recover costs in a reasonable time period. If the procedures presented in this report are implemented, not only will annual school budgets decrease, but facilities will also have a method to conserve energy in the present and future.

The target audience includes facility managers, school officials, and school owners who would like to be more informed about how to perform an energy audit at their own facility and to understand why energy audits are worth performing. Although building audits have associated costs, including time and investment to conduct an audit and implement recommendations, the potential to recover costs can be great. At the beginning of the twenty-first century, the average public school building in the United States was 42 years old with 28 percent of school buildings built before 1950, and each will likely be occupied for years to come (National Clearinghouse for Educational Facilities, 2012). This means that since educational buildings are occupied for such a long period of time, recovering costs for implementing energy-efficient components likely will occur while the building is still functioning.

This report is designed to address these issues in the following sections: First, Chapter 2 discusses the background and purpose of building energy audits while Chapter 3 focuses on the minimum acceptable energy efficiency requirements for building renovations for educational facilities. Next, Chapter 4 establishes and discusses the requirements of the selected minimum code/standard, and Chapter 5 focuses on the procedure and analysis of energy audits. Chapter 6 addresses common energy use deficiencies in educational buildings, and Chapter 7 establishes the cost analysis method to apply to possible building modifications. Focusing on an example, Chapter 8 describes an energy audit from John Paul II Catholic Elementary School. To conclude, Chapter 9 discusses the future of energy audits, and Chapter 10 reinforces the importance of building energy audits and offers recommendations that have the potential to reduce energy consumption. Finally, the Appendices provide supportive documents and additional details related to the recommendations contained in the report as well as documents that can be used by educational facilities to conduct their own energy audits, including an example building energy audit in Appendix A. Depending on the level of understanding needed, the reader may read the report sections in the order presented or choose only those chapters that address particular issues.

Chapter 2 - Background

This chapter delves into the history and purpose of conducting building energy audits. While they have changes a lot from their original form, the main goal has remained the same: reduce energy consumption and create more energy-efficient buildings.

History of Energy Audits

During the 1970's energy crisis connected to the 1973 Arab Oil Embargo of OAPEC, the energy prices rose dramatically along with the realization that energy sources might not be able to keep pace with the population's consumption (Wulfinghoff, 2000). The threat of limited energy resources launched the need for energy conservation measures and the creation and utilization of energy audits (Wulfinghoff, 2000). Throughout the 1980's and 1990's, energy prices dropped considerably due to a discovery of substantial crude oil, and energy consumption was no longer a worry. However, the oil surplus found in the 1980's is no longer able to sustain the world's energy consumption, and energy conservation has once again become a focus as prices continue to rise. Figure 2-1 depicts the crude oil price per barrel since 1970 and the steady rise in energy costs, emphasizing the energy crisis of 1973. Electricity and natural gas have typically followed the same pattern as that of crude oil (Mohammadi, 2009).

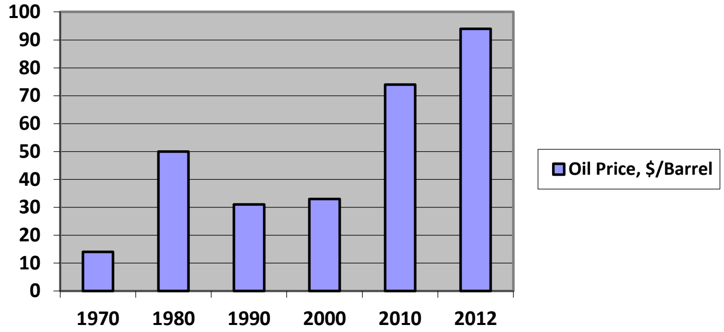


Figure 2-1 History of Crude Oil Prices (Bloomberg, 2012)

Building owners and facility managers are looking at how to more effectively reduce energy use because of increased utility costs, frequently using energy audits to uncover energy conserving measures. To improve the school buildings though requires finances. Therefore, energy reduction tax incentives and rebates are being developed and promoted by individual states and private companies to push building improvement (Energy Audit Institute, 2010). By encouraging energy-efficient behavior and offering incentives and rebates, school facilities can implement more energy-efficient building components that consume less energy and save operational funds overall. In particular, many incentives and rebates are available for energy reduction strategies in new and existing buildings (U.S. Department of Energy, 2012b). For example, a tax deduction is available until December 31, 2013, for eligible efficiency technologies such as lighting controls/sensors, caulking/weather stripping, and building insulation (U.S. Department of Energy, 2012b).

Audits began as a rudimentary energy conservation tool and have evolved into detailed reports and analyses. First recorded in the 1970's, energy audits were not formalized procedures, but rather assumptions of what might save energy in a building. Information was gathered in a pen-and-paper fashion and studied without involving much technology. The recommendations that were developed out of the energy audits were based on mere assumptions, not always proven modifications that would lead to economic savings. However, as technology has developed and processes have improved, so have building energy audits. Now, building energy audits incorporate spreadsheets, digital pictures, and economic analyses.

Moreover, the building design and construction industry has encouraged energy audits to evolve over time. These efforts have been guided and encouraged by federal legislation and private programs to reduce energy consumption in both new construction and existing buildings with initiatives such as the Energy Policy Act (EPACT) 2005 and United States' Green Building Council's Leadership in Energy and Environmental Design (LEED) program (Schultz, 2011). These two initiatives help determine recommendations for building energy efficiency improvements. First, the EPACT 2005 defines a number of energy management goals to establish building performance standards, such as lighting and water use standards (U.S. Environmental Protection Agency, 2005). Meanwhile, LEED "provides building owners and operators with a framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions" in existing buildings (U.S. Green Building Council, 2012). LEED has a very structured system outlining what a building should have to meet its standards; however, LEED is a building rating system rather than an energy code/standard, and as such, it was not considered as a baseline for this report. (Baseline standards are discussed further in Chapter 3–Selection of the Minimum Acceptable Energy

Requirements) As exemplified in such initiatives, energy saving measures are constantly being improved, starting with government standards outlining energy conserving practices and how to implement building energy audit recommendations. While first triggered in response to the energy crisis in the 1970s, now such audits are used to save energy, decrease utility bills, and to take advantage of energy efficiency incentives.

Purpose of Energy Audits

Specifically, energy audits identify energy use among the various services within a building, depict opportunities for energy conservation measures, and provide sufficient information for the owner/operator to understand energy use characteristics of their building. The main goals of an audit are to detect operating problems, identify potential modifications to decrease energy use, and optimize the performance of existing buildings (Alajmi, 2011).

Also, energy audit results can be used to reduce energy use in areas where energy is being wasted. This could include improving the efficiency of equipment within a functioning system, reducing energy use by proper operation and maintenance of the equipment, decreasing occupant energy use, and ultimately saving energy utility costs (Wah, 2001). Next, operating problems are those associated with how occupants behave in the building, their habits and schedules, how the building is functioning, and equipment operation. For example, leaving lights on in unoccupied rooms wastes energy, and keeping the thermostat setpoints very low in the summer when spaces are not occupied can cool rooms. Energy audits also can help the user detect potential modifications to decrease energy use within their building. Meanwhile, to decrease energy consumption, energy audits can help suggest improvements such as sealing building envelope components to allow for less heat gain and loss, sealing joints and seams to prevent drafts from entering the space, and monitoring the temperature settings to create comfortable working environments. Optimizing performance and reducing energy consumption within buildings are main priorities of energy audits and will be discussed much further in Chapter 6 – Common Deficiencies Identified by Audits.

ASHRAE Audit Procedure

To help school systems avoid wasting money on unnecessary utility spending and instead focus resources where they can have the most impact requires energy audits (Schultz, 2011) as specified by the American Society of Heating, Refrigerating and Air Conditioning Engineers

(ASHRAE). A reference guide published by ASHRAE, the Procedures for Commercial Building Energy Audits, categorizes current audit procedures into three levels of analysis (ASHRAE, 2011): Level I Analysis—Walk-Through Analysis, Level II Analysis—Energy Survey and Analysis, and Level III Analysis—Detailed Analysis of Capital Intensive Modifications (ASHRAE, 2004). Each level is more intensive and more costly, but the results lead to greater potential for energy savings. This guidebook, in its second edition, provides information on what to expect from an audit and shows how to conduct effective energy audits that can lead to actionable audit reports.

Level I Analysis – Walk-Through Analysis

The first level of analysis involves a walk-through of the building and is the least time-intensive. Before the audit begins, the auditor should gather and analyze the historic utility usage and cost, if data is available. Then, the audit should proceed with a brief on-site survey by the auditor to become familiar with the building's construction, equipment locations, operations, and maintenance procedures. He/she should be sure to ask building personnel if any maintenance problems and/or practices are known that may affect the building's efficiency. The Level I audit is geared toward identifying potential energy improvements and understanding the general building configuration. From the audit report's detailed findings, potential simple improvements with no/low cost can be discovered that could lead to energy savings. The Level I audit is intended to help the auditor understand how the building performs in terms of energy, establish a baseline for measuring improvements, and deciding whether further evaluation is warranted.

Level II Analysis – Energy Survey and Analysis

The Level II analysis incorporates the Level I audit plus a more detailed building survey and energy analysis. The purpose of a Level II audit is to identify and provide the savings potential and cost analysis of all practical measures that meet the owner's constraints and economic criteria and to discuss any changes to operation and maintenance procedures. The modifications suggested by a Level II audit typically include no-to-low-cost options to potentially capital-intensive improvements. Since many improvements have a higher potential for being capital-intensive, more thorough data collection and engineering analysis is required.

Ultimately, the economic analyses must aid the facility manager in determining feasible building modifications.

The Level II building survey becomes more complex because the audit focuses upon all design systems and components within a building including building equipment operation, building envelope, mechanical systems, lighting systems, electrical systems, and water use. Also, the ASHRAE Procedures publication suggests that after the audit is conducted, a list of recommended measures should be created along with estimated costs and financial payback performances.

Level III Analysis – Detailed Analysis of Capital Intensive Modifications

The third level of energy analysis incorporates all of the elements of a Level II audit plus a more rigorous engineering analysis of proposed modifications. The energy audit should include on-site measurements, metering, and monitoring to assist in clarifying not only the operating characteristics within the building as a whole, but also the situations that cause load profile variations on short- and long-term bases. This means the data collection is much more detailed and takes weeks or months. Furthermore, a unique aspect of the Level III audit is the incorporation of building energy modeling software, for example EnergyPlus, which models the heating, cooling, lighting, ventilating, water and other energy flows in buildings to show visually where energy is being used and where it can be conserved (U.S. Department of Energy, 2012a).

To better demonstrate the differences among levels, Table 2-1 depicts the audit procedure steps side-by-side for each level. Each “X” represents that the associated procedure step is performed within that level.

Table 2-1 ASHRAE Audit Level Comparison

	ASHRAE Audit Levels		
Audit Procedure Steps	**Level I**	**Level II**	**Level III**
Interview with Personnel	X	X	X
Review Utility Bills	X	X	X
Walk-Thru the Building	X	X	X
Detailed Building Survey		X	X
Data Collection over Weeks or Months			X
Simplistic Recommendations	X	X	X
Detailed Recommendations		X	X
General Costs and Economic Analysis Provided		X	X
Bid-Level Construction Cost Estimating			X
Computer Simulation			X
Audit Report	X	X	X

This report used the ASHRAE procedure guide as the main reference in suggesting the audit criteria for school buildings because most of the other guidebooks available also reference ASHRAE's three levels.

Moreover, this report suggests the use of audit Level II to permit the auditor to gather all of the building system information in a simple method while still requiring economic analyses to be performed from both short- and long-term perspectives. To gather a greater amount of detailed information simply requires the audit procedure provided in the next chapter and the worksheets in Appendix B. By choosing a documented and accepted audit level, auditors have a ready support if needed.

Audit Importance in Educational Facilities

Energy audits focus on saving energy and building operations costs to allow educational facilities to meet overall reduced annual budget goals (Oliff, 2012). Nationally, K-12 schools spend more than $6 billion a year to facilitate the education of children and the operation of the facilities (Kelderman, 2008). If the money does not have to be spent on heating or cooling buildings, then it can be used for education. However, schools have a problem supplying high start-up investments for building renovations due to tight budgets and so would much rather focus on the lifetime/operational budgets of building components. Accordingly, by conducting energy audits in schools, auditors can calculate the payback period of specific improvements with long-term investments in mind. "Efficiency investments in the schools make enormous sense for taxpayers, the environment, and educators" because "these investments save money, reduce pollution and perhaps more importantly they bring teachers and students into the loop – ensuring that the next generation will be fully engaged in shaping our energy future" (US Fed News Service, 2008).

Potentially, many items and pieces of equipment can be renovated or upgraded to help reduce energy consumption. The main factor behind what should be changed and when is the capital available to initiate the modifications. The following paragraphs describe school districts that have either upgraded their facilities or are looking into upgrading.

In Marion County, Florida, Public Schools have been educating occupants about energy conservation methods, teaching energy-efficient behaviors, and monitoring power consumption since December 2005. The district began the program by shutting down computers overnight and turning off the lights when spaces were unoccupied (Callahan, 2012). By implementing this fairly simple conservation plan, the school district has been able to reduce electricity costs every year. Over the last seven years, the district has cut its annual electric usage by 12.5 percent resulting in tax dollars totaling $176,500 per month being redirected to other educational programs (Callahan, 2012).

As proof of how occupancy affects energy usage, Kitsap County elementary school utility usages vary quite drastically depending on community usage. This underscores the fact that while many schools need upgrades and energy-efficiency remodels, usage of the schools really dictates the energy bills. For example, the Breidablik elementary school, founded in 1990, needs approximately $641,000 worth of work to update the building (Phan, 2012). However, the building also has the cheapest utility bills across the entire district with $40,032 in 2011 because the building is rarely used after school hours (Phan, 2012). In contrast, the Vinland elementary school, opened in 1994 and also requiring major renovations of about $440,000 had a much higher utility bill of $131,000 in 2011 (Phan, 2012). The two schools are very similar in size, student population, construction date, and renovation needs, yet there is a large difference in annual utility bills because of increased building occupancy hours by community members using the school for town and organizational meetings. In this case, an audit could help prescribe the teaching of energy-efficient behaviors to help save money since the reason for higher utility bills in the second school revolves around occupants' habits.

For schools to continue to provide exceptional educations to children while overcoming budgetary restrictions, energy and water utility bills must be reduced, which means schools need to focus on adapting their behavior and implementing energy saving measures. The following chapters will depict the minimum energy requirements for building renovations, common deficiencies identified in audits, and economic analyses to evaluate viable recommendations.

Chapter 3 - Selection of the Minimum Acceptable Energy Requirements

The first task in conducting analyses of educational facilities is to determine the most appropriate energy standard for upgrades of existing facilities. Selecting an energy standard establishes the minimum accepted level for energy efficiency for operation of existing facilities. Such energy standards also set criteria of construction and performance when renovating or replacing components. To aid in selecting an energy minimum standard, the Department of Energy (DOE), an all-encompassing United States resource for energy consumption issues, provides references to industry-accepted publications.

The minimums specified by industry-accepted energy codes/standards identify required building components to reduce energy usage. Furthermore, selecting an industry-accepted and -supported energy standard ensures that the content is vetted, regularly used, reviewed, and updated by others, which will reduce the effort to stay current because these documents are typically updated routinely. To find the best and most applicable energy standard for this comparison, required two primary factors: First, a review of what each state has accepted for its statewide minimum to understand the popularity of industry-accepted standards, and second, the DOE recommendations regarding published energy standards. The following subsections will identify and discuss the industry-accepted energy standards and further explain the decision-making process in selecting an energy standard as a minimal construction and operational baseline for educational buildings.

Accepted Energy Codes and Standards

Using an existing energy code or standard as the basis for recommendations in this report allows for well-defined requirements that are industry-accepted and well understood. The two most prominent energy-efficiency codes or standards in the United States are the International Energy Conservation Code (IECC), published and maintained by the International Code Council (ICC), and the ANSI/ASHRAE/IES Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings (ASHRAE 90.1). In addition to these two, references are available that focus on specific climates, high performance, green/sustainable design, and statewide enforced requirements that exceed the minimum requirements of ASHRAE Standard 90.1-2010. The ICC publishes the International Green Construction Code (IGCC), and ASHRAE publishes Standard 189.1 for the Design of High-Performance, Green Buildings (ASHRAE 189.1). Neither the IGCC nor ASHRAE 189.1 was considered because they are newly introduced and very few jurisdictions have adopted them. From a statewide perspective, a few states have their own accepted energy guidelines to follow, for example, California with Cal Green, Indiana with the 2010 Indiana Energy Conservation Code, and Michigan with the 2009 Commercial MI Uniform Energy Code Rules (Department of Energy, 2012). Moreover, individual statewide/jurisdiction codes/standards were not considered for this report since each state has a different policy, which would have precluded common audit recommendations. Notably, exceeding the minimum code requirements allows for even greater energy savings; however, such facility upgrades are also more expensive. Therefore, these documents should be referenced only if the goal is to achieve energy savings above those provided by the IECC and ASHRAE Standard 90.1.

The DOE recognizes both the IECC and ASHRAE Standard 90.1 as acceptable documents; meanwhile, energy codes are adopted on a state-by-state basis, even though the DOE has established minimums to which the states must adhere by the enforced dates. The DOE also requires that a state's commercial building energy code regarding energy efficiency must meet or exceed ASHRAE 90.1-2010 by July 20, 2013 (Department of Energy, 2011a). Finally, all states have two years to adopt ASHRAE Standard 90.1-2010 or upgrade their existing commercial building codes to meet or exceed its requirements (Department of Energy, 2011a). Figure 3-1 depicts the current state adopted energy codes for commercial construction, as updated in August 2012 and provided on the DOE website.

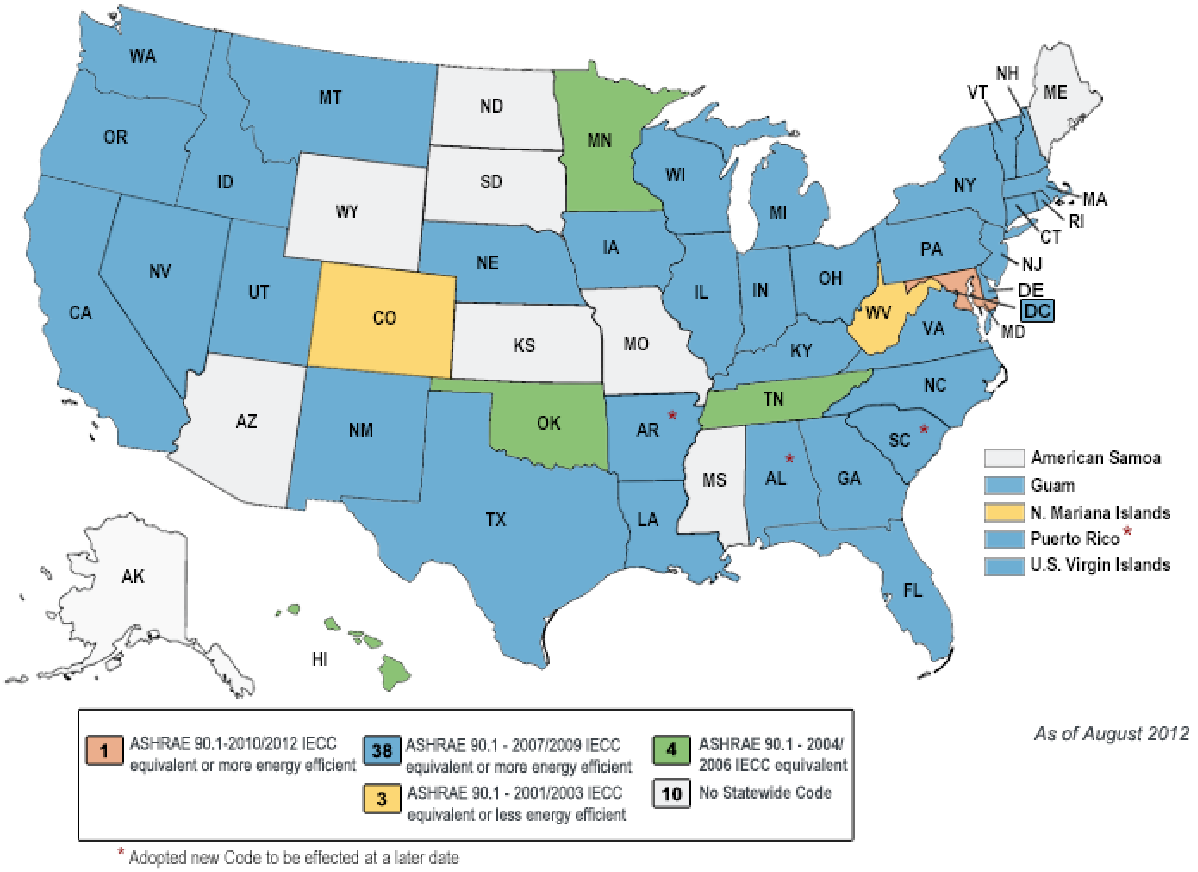


Figure 3-1 Status of State Commercial Energy Code Adoption (Department of Energy, 2011a)

The IECC, as with most of the International Code Series, is predominantly referenced by code officials, whereas ASHRAE Standard 90.1 is more familiar to design professionals. Both address very similar content (building envelope, heating, cooling, ventilation, service water heating, power, and lighting), and many of the same industry professionals involved in their development. IECC specifically states in Chapter 5–Commercial Energy Efficiency that meeting the requirements of ASHRAE Standard 90.1 is an accepted alternate compliance path. Therefore, since ASHRAE Standard 90.1 is geared to individuals selecting equipment and analyzing performance, this report will use it as the minimum level of acceptable construction and operation.

In addition to providing the minimum requirements for energy-efficient design and construction of most buildings, ASHRAE Standard 90.1 offers, in detail, the minimum energy efficiency requirements for the design and construction of new buildings and their systems, new portions of buildings and their systems, and new systems and equipment in existing buildings as well as the criteria for determining compliance with these requirements (ASHRAE, 2010). ASHRAE publishes a revised version of the standard every three years, continually tightening the requirements to reduce energy consumption and increase building efficiency (ASHRAE, 2010). The most current version of ASHRAE Standard 90.1 was published in 2010, with a new version planned to be published in 2013. Using the 2010 version for the minimum construction and performance criteria, as opposed to earlier versions, is appropriate for this report because the DOE has issued mandates, also known as determinations, to push the building industry towards even greater energy-efficient design and utilization. These determinations establish requirements that must be met by a stated time.

Chapter 4 - Minimum Construction and Operational Requirements for Renovations

ASHRAE Standard 90.1-2010 is the suggested design minimum for educational facilities in this report as it establishes minimum requirements for both new facilities and renovations to existing facilities. Since the research purpose is to improve energy efficiency in existing facilities through renovations, the requirements defined by ASHRAE Standard 90.1-2010 should be consulted and the requirements of the document understood. Of course, as energy codes continue to advance and newer editions are published, facility managers should consider adopting them.

ASHRAE Standard 90.1-2010 addresses energy efficiency requirements for all aspects of buildings, from the building envelope to specific building systems. Typically, the ultimate goal of meeting the energy efficiency requirements is to confirm that the changes being made will improve a building's energy efficiency. To know when to apply the requirements of ASHRAE Standard 90.1-2010 to a building addition or renovation, users should see Subsection 4.2—Compliance Paths within ASHRAE Standard 90.1-2010 (ASHRAE, 2010).

Table 4-1 displays the requisite sections of ASHRAE Standard 90.1-2010 for renovating an existing building, with discussion about the sections' content following the table. The minimums established in the sections of ASHRAE Standard 90.1-2010 only apply to new construction, additions, or significant renovations when adopted, but for the purposes of this report, these minimums should also be considered as the baseline for all improvements to existing facilities.

Table 4-1 Applicable Sections of ASHRAE Standard 90.1-2010

Section Number	Section Title
3	Definitions, Abbreviations, and Acronyms
5	Building Envelope
6	Heating, Ventilating, and Air Conditioning
7	Service Water Heating
8	Power
9	Lighting
10	Other Equipment
Normative Appendix B	Climate Zones

ASHRAE Standard 90.1-2010 Section 3 defines certain terms, abbreviations, and acronyms that are applicable to the standard (ASHRAE, 2010). The definitions are applicable to all sections of the standard and help to clarify what is being described and specified.

ASHRAE Standard 90.1-2010 Section 5 addresses the building envelope (ASHRAE, 2010). For this section, readers must know the type of spaces being designed and how they are thermally conditioned. Most educational facilities will feature a single type of conditioning, referred to as “nonresidential conditioned,” to encompass classrooms, office areas, gymnasiums, and so forth (ASHRAE, 2010). Subsection 5.4 addresses the requirements for insulation, as well as maximum areas allowed for windows and doors (ASHRAE, 2010). This section also addresses the requirements to reduce air leakage, such as vapor barriers, caulking, and sealing (ASHRAE, 2010). Adhering to the conditions of Section 5 can reduce heat losses and gains in the building (ASHRAE, 2010).

Section 6 of ASHRAE Standard 90.1-2010 focuses on the building’s heating, ventilating, and air-conditioning (HVAC) system(s) (ASHRAE, 2010). The building must follow the provisions in Subsections 6.4–Mandatory Provisions and 6.5–Prescriptive Path. This section provides equipment efficiencies along with specifications for controls, system limitations, and requirements (ASHRAE, 2010). Compliance with the requirements in Section 6 allows for the design of an efficient HVAC system and controls, thereby reducing building use.

Service water heating is addressed in Section 7 of ASHRAE Standard 90.1-2010 (ASHRAE, 2010). Subsection 7.4 concentrates on the mandatory provisions, including how to calculate hot water loads, efficiencies of equipment, and pipe insulation (ASHRAE, 2010). The section also addresses controls for the service water heating system, as well as outlet temperatures (ASHRAE, 2010). Implementing the requirements in Section 7 will produce an efficient service water heating system well-suited for the needs of the facility.

Section 8 of ASHRAE Standard 90.1-2010 addresses the power distribution within a facility (ASHRAE, 2010). Specifically, Subsection 8.4 focuses on the mandatory provisions of the power system (ASHRAE, 2010) such as maximum voltage drop for feeders and branch circuits and methods for automatic receptacle control (ASHRAE, 2010). The purpose of section 8 is to design a power system for the facility that reduces unnecessary loads and ensures that the voltage drop in the system is not too high.

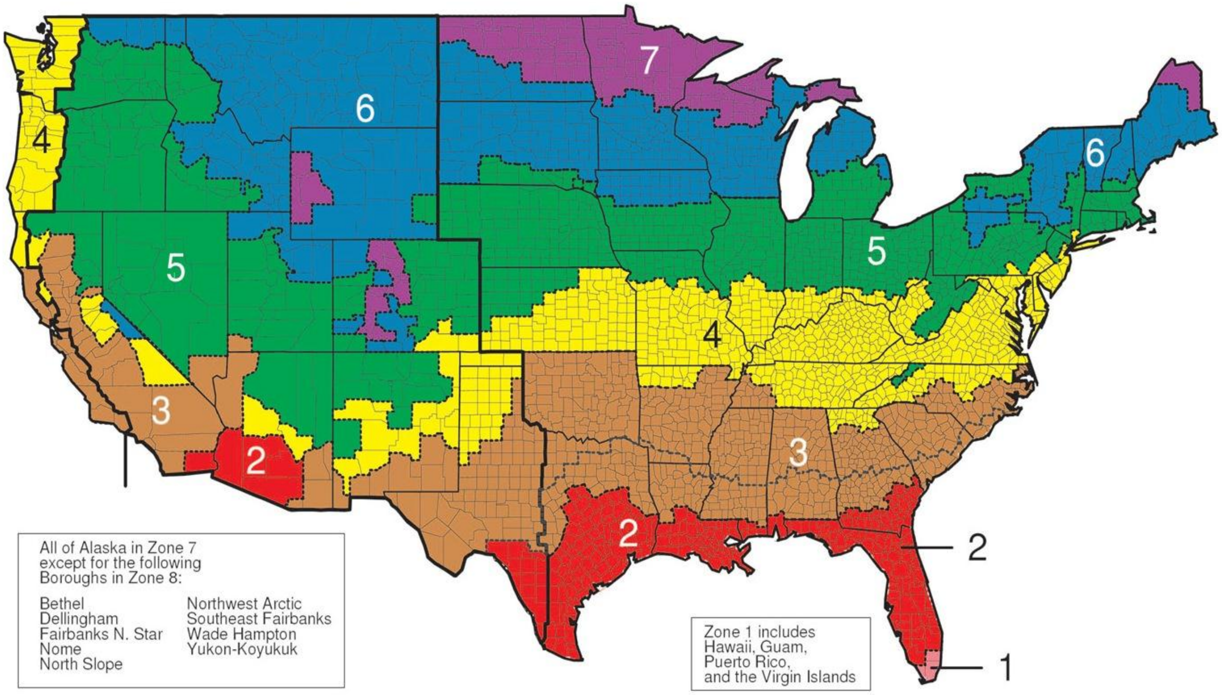
Lighting is addressed in Section 9 of ASHRAE Standard 90.1-2010 (ASHRAE, 2010), and Subsection 9.4 offers mandatory provisions for lighting (ASHRAE, 2010). This section deals with lighting controls, including automatic control, such as occupancy sensors, vacancy sensors, and time clocks (ASHRAE, 2010). Lighting power densities, the maximum wattage per square foot, is also addressed in Subsection 9.4 (ASHRAE, 2010). In particular, the building area method for calculating the lighting power allowance is the simpler of the methods in the standard and is appropriate for educational facilities. Applying Section 9 requirements will reduce lighting loads, increase efficiency since the power consumption is limited, and improve controls, thereby reducing energy consumption and lowering utility costs.

Section 10 of ASHRAE Standard 90.1-2010 addresses energy requirements for any other building equipment not covered in the earlier sections, for example, electric motors, service water pressure boosters, and elevators (ASHRAE, 2010). Ultimately, Section 10 covers efficiency for all aspects of the building. Table 4-2 depicts the items included in ASHRAE Standard 90.1-2010 by system section and as such is a reference for the minimum requirements dictated by the standard. Take note that the asterisks (*) in the table represent sections in the ASHRAE Standard 90.1-2010 that are not practical for existing building renovations, due to financial investment required to implement revisions, or that are simply not practical for existing buildings.

Table 4-2 ASHRAE 90.1-2010 Content per System Section

Document Section	Items Discussed with Section Number
5. Building Envelope	Air Leakage (5.4.3) Fenestration Requirements (5.5.4) Building Envelope Thermal Requirements per Climate Zone (Tables 5.5-1 – 5.5.8)
6. Heating, Ventilating, and Air Conditioning	Minimum Equipment Efficiencies (Tables 6.8.1A – 6.8.1K) Controls (6.4.3) System Insulation (6.4.4) Economizers (6.5.1) * Simultaneous Heating and Cooling Limitation (6.5.2) Hydronic System Design and Control (6.5.4) Heat Rejection Equipment (6.5.5) * Energy Recovery (6.5.6) * Exhaust Systems (6.5.7) Radiant Heating Systems (6.5.8) *
7. Service Water Heating	Equipment Efficiency (7.4.2) Piping Insulation (7.4.3) System Controls (7.4.4) Pools (7.4.5) Heat Traps (7.4.6) *
8. Power	Voltage Drop (8.4.1) * Automatic Receptacle Control (8.4.2) *
9. Lighting	Interior Lighting Power Allowance (9.2.2.1 & 9.2.2.2) Lighting Controls (9.4.1.1 – 9.4.1.7) Daylighting (9.4.1.4 – 9.4.1.5) Exit Signs (9.4.2) Exterior Lighting Power Allowance (9.4.3)
10. Other Equipment	Electric Motors (10.4.1) Service Water Pressure Booster Systems (10.4.2) Elevators (10.4.3)
* **Denotes that the standard section is not practical for existing building systems, due to financial investment, difficulty to implement, or lack of application for existing buildings.**	

ASHRAE Standard 90.1-2010 Normative Appendix B deals with climate zones for the United States (ASHRAE, 2010) as identified in Figure 4.1. A climate zone is based on location and county, with specific counties listed in ASHRAE Standard 90.1-2012 Appendix B, Table B-1. Figure 4-1 shows more clearly how the counties are divided between climate zones, which are then broken down even further into moisture categories represented by letters: A—humid, B—dry, and C—marine (ASHRAE, 2008 & ASHRAE, 2010). Climate zones are referenced throughout ASHRAE Standard 90.1-2010, with varying requirements based on the climate zone in which a project is located. For example, the state of Kansas falls into two different climate zones, 4 and 5 depending on the specific county; however, Kansas is either 4A or 5A because it is classified as a moist climate (ASHRAE, 2010).



© 2003 *ASHRAE Transactions* 109(1):109-121, Briggs, et al.

Figure 4-1 ASHRAE Climate Zones for the Continental United States (ASHRAE, 2010)

While ASHRAE Standard 90.1-2010 focuses on building efficiency, it does not address water use. Therefore, in this report, from a water usage standpoint, the Energy Policy Act (EPACT) 2005 will act as the prime guideline for water use in educational facilities. The EPACT 2005 includes numerous energy management goals and serves several areas including metering and reporting, energy-efficient products, energy savings performance, building performance standards, renewable energy requirements, and alternative fuel usage (U.S. Department of Energy, 2005). This policy is enforced federally and, therefore, is already an accepted parameter for water consumption.

Chapter 5 - Performing and Analyzing Audits

This chapter is structured as an instruction manual for an auditor or auditing team. It details the recommended procedure for performing building energy audits on educational K-12 facilities and describes how to analyze the compiled results from an energy audit. The goal is to reduce energy use and water consumption in areas where energy is being wasted and in areas where a reduction will not disrupt any occupant functions.

Procedure Guide

The first task of the energy audit procedure is to determine when to perform the audit. This is best done when the temperature outside is more than 20°F different from the interior building temperature. Having contrasting temperatures allows for a clearer temperature difference when testing for infiltrating outside air. Also, performing the audit while the spaces are occupied is best because it will accurately display occupant behaviors. The three main sections, 1) Pre-audit, 2) Audit and 3) Post-audit, are described in detail in the following subsections. The energy audit documents and the step-by-step audit procedure are located in Appendix B.

Pre-Audit

The initial step in conducting an energy audit is to collect the building's utility (electricity, natural gas, water, etc.) bills for at least one year and preferably three. Once gathered, review the monthly bills, looking for patterns of irregularity or anomalies. Irregular patterns could be spikes or dips of energy use or water consumption and months of constant energy usages. Also, review the monthly bills for opportunities to obtain a better utility price by taking advantage of different utility rate structures. Depending on the utility company, facilities can lower their utility rates based upon their amount of consumption and associated demand rates.

Thorough and consistent evaluations are important, and using the worksheets provided in Appendix B will facilitate consistency in data gathering. The audit worksheets are based upon the ASHRAE guidebook, Procedures for Commercial Building Energy Audits, and formatted similarly to the Washington State University energy guide (ASHRAE, 2011 & Washington University, C. E., 2003). Completing as much of the building information gathering task as possible before beginning the audit will facilitate the process. If building floor plans are available, use the plans to fill out the audit forms and to become familiar with the building characteristics and components. After reviewing the utility bills and assembling building information, compile a list of questions for the owner/operator. The questions might address irregularities seen in the monthly bills or questions about the building floor plans. Some example questions follow:

- What are the exterior wall materials?
- Are there any large, power-drawing activities throughout the year? (Fundraiser night, ice cream socials, etc.)
- Where is the heating/cooling equipment housed?
- Are there any large water-consuming activities?
- What building upgrades, if any, are not shown on the plans?

Some useful tools to bring on an audit include a flashlight, camera, thermal camera (if available), light meter, thermometer, clipboards, writing instruments, the building floor plans, and the audit forms in Appendix B. The audit form worksheets can be used to organize collected data concisely and to confirm that all relevant data was collected. Appendix B contains an individual room spreadsheet and an entire building spreadsheet. Appendix B also contains a tool guide with descriptions of each of the tools listed above and alternative options if certain tools are not available.

The individual room worksheet for every room requires temperature data, lighting data, equipment data, and building envelope data to be collected. Then, the entire building worksheet summarizes the results from all of the individual room worksheets, and it includes sections for mechanical system information, plumbing system information, and other overall building details. The intent of the worksheets is to collect large quantities of data in an organized and thorough manner to minimize time invested conducting the audit, as well as to accurately record information.

Audit

Begin the audit with a brief tour of the facility to become familiar with the building layout. After that, try to get answers for any pre-audit questions, and then proceed with the detailed building survey. Gather detailed descriptions of equipment and take photographs to reference later. While completing the detailed building walk-through, collect exit questions that might require input from occupants or maintenance staff, such as equipment operation schedules and equipment cleaning cycles. The following sub-sections detail what items should be noted and characteristics to observe while conducting the audit and completing the audit worksheets including the space thermal conditions, lighting, building envelope, heating/cooling system, and plumbing information.

Space Thermal Conditions

Within each room, record the temperature of the space. Also, if there is a thermostat located in the space, observe the type of thermostat (traditional dial type, programmable, etc.), the location of the thermostat, and the temperature set points for heating and cooling. When observing the thermostat, check to see if any programming schedule has been implemented and is being used.

Lighting

Within each space, record the type of fixtures, the number of fixtures, the type of lamp within the fixtures, and the number of lamps per fixture. Take note of are any inoperable lamps or fixtures. Next, measure the light levels in the areas of occupant activity (blackboard area, student desktops, etc.). To be consistent throughout all rooms, choose a steady height from which to take the measurements, such as the students’ desk height. While in the space, note whether the lights are on or off in relation to whether the space is occupied or not. For example, would the lights be on or off during school hours versus weekend hours? Also, the lighting control method is an imperative data item to note (toggle, motion sensor, keyed switch, dual-level switching, occupancy sensor, daylight sensor, etc.).

Linear fluorescents lamps in ceiling fixtures can be difficult to identify without reading the label; however, doing so adds the inconvenience of carrying a ladder from room to room. Another way to identify linear fluorescents lamps is by their diameter as shown in Figure 5-1.

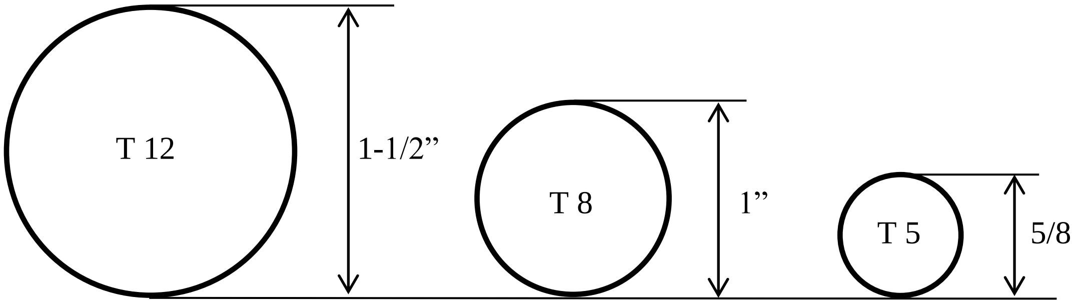


Figure 5-1 Linear Fluorescent Diameter Comparison

Building Envelope

Record all of the windows and doors within the space, noting both the location and size of the assemblies and the type of window or door such as single-pane windows, double-pane windows, wood frame, aluminum frame, etc. While assessing the windows and doors, check for air leakage around the seals either by taking thermal photographs of the joints or by feeling for incoming air around the seals. Record the exterior wall and roof construction, including insulation information if known. Most likely, the construction information can be found on the building floor plans, but it is important to verify that the information is accurate as sometimes improvements will have been made and not recorded or the building may not have been constructed per the plans. Also, while walking around the building, both internally and externally, observe any irregularities. These irregularities could be unexpected construction techniques, sealing around the openings, etc. If available, use a thermal camera to assess joints and seals around the building and thereby locate sources of infiltration.

HVAC System

Take photographs to document the name plate of every piece of equipment and its general location. While assessing the equipment, make sure to document the manufacturer, model number, type of equipment, fuel source, size of equipment, and other items on the audit forms from Appendix B. When examining the heating and cooling components, make sure to analyze both the power plant equipment and the room equipment. For example, a boiler that serves multiple room radiators is the plant equipment, while the radiators are individual room equipment.

Plumbing

Record the number and type of all water-consuming fixtures in the building. Make sure to note the water usage data for the fixtures, such as the gallons-per-flush (GPF) or the gallons-per-minute (GPM) of flow to reflect the building's water usage and therefore, utility bills. Document the hot water discharge temperature flowing from the lavatory faucets and how quickly the hot water comes from the faucet. The readings should be taken from multiple faucets if possible, to obtain accurate average water discharge temperatures. Also, note the faucet and flush valve control (manual control or sensor operation).

Much like for the HVAC equipment, make note of the water heating equipment. Take photographs to document the name plate of the equipment and its general location. While assessing the equipment, make sure to document the manufacturer, model number, type of equipment, fuel source, size of equipment, and other items on the audit forms from Appendix B.

Post-Audit

After the audit, input the collected information onto the audit worksheets. Develop any questions, and take a second look at the component, or contact a facility manager who would have the knowledge. Also, catalog and title all photographs from the audit for documentation and reference purposes. Once all data has been entered, begin analyzing the findings.

Analysis

The auditor will want to look for areas not complying with energy code standards within the building, or for items that are in obvious need of attention. Compliance issues are going to be covered in ASHRAE Standard 90.1-2010 and EPACT 2005 and may include lamp choices, types of windows installed, insulation around ductwork, and non-sealed penetrations, among others. The following list relates the contents of the standard to individual building components (ASHRAE, 2010):

- Section 5: Minimum thermal requirements for building envelope assemblies.
    - U-Values for windows and walls
    - Number of windows, envelope openings
- Section 6: Space heating/cooling, the associated controls and mechanical equipment.
    - Equipment efficiencies
    - Thermostatic controls

- Section 7: Water heating equipment, controls, and maximum outlet temperatures.
    - Equipment efficiencies
    - Piping Insulation
    - Controls
- Section 9: Lighting data.
    - Lighting power density
    - Controls

Some of the items in obvious need of attention might be leaking window seals, out-of-date lamps, and non-low-flow plumbing fixtures. To address such issues, the following subsection will describe a method to determine recommendations from the collected results.

Recommendations from Results

To make educated recommendations, each possible improvement must first be analyzed from an economics standpoint to determine financial feasibility, which is covered in Chapter 7–Cost Analysis. However, before economic analyses can be performed, the auditor must be able to realize what components are causing energy problems. Common deficiencies found in educational facilities are often associated with thermostat controls, lighting systems, infiltration issues, and occupant behavior.

Without experience with building operation and construction, an auditor may have difficulty addressing and gathering building deficiencies. However, Appendix C provides a checklist of possible building deficiencies and accompanying possible solutions for each building system (Washington State University, 2003). The list is not all-inclusive, but it covers many common modifications that could be applicable to K-12 facilities. The checklist is broken down into common categories: room/thermal conditions, lighting and power, building envelope, HVAC, plumbing, and building occupancy. The checklist first asks if a certain problem exists within the building, and then gives possible energy measures for a building.

In addition to comparing the building energy audit results to a baseline energy efficiency standard and checking the economic feasibility, analyze one year of energy and water utility bills, and preferably three. With the collected data, graph the consumption per month, which permits tracking and analyzing utility usage trends. When looking at the utility data, look for odd amounts of consumption and anomalous months. There is an example of analyzed utility data in Chapter 8–Energy Audit at John Paul II Catholic Elementary School. Meanwhile, Chapter 6 will further discuss common deficiencies found in K-12 facilities.

Chapter 6 - Common Deficiencies Identified by Audits

This chapter describes common building deficiencies determined from gathered building energy audit data. The chapter outlines both physical modifications and occupant behavioral adjustments to decrease energy and water consumption. The building deficiencies were determined by reviewing many individual building audits, as well as by researching energy saving building modifications (Department of Energy, 2007).

Physical Building Modifications

Many modifications for existing buildings are possible to improve the energy efficiency of the systems, reduce cost in the building operating systems, and enable funds to be redirected to more pressing educational needs; therefore, such modifications are crucial. The following subsections will outline potential adjustments to building envelope, equipment, and internal systems from no-/low-cost up to significant initial investments.

Adjustments to Equipment and Systems

The opportunities within each subsection appear in order of those requiring the least financial investment to those requiring the greatest capital investment. The subsections also correspond to the items on the checklist in Appendix C and include space thermal conditions, lighting and power systems, building envelope, HVAC systems, and plumbing systems.

Space Thermal Conditions

The simplest method to conserve energy is to reduce the heating/cooling requirements of building spaces. For example, automatic controls or trained users can conserve energy, often by turning off lights and regulating temperature. To reduce the radiated heat from the lamps and thermal load, and to decrease air conditioning demand.

Also, implementing thermostat programming (such as temperature setbacks) within buildings is key to reducing energy consumption. Instead of manually adjusting thermostats, facility managers can install a programmable thermostat to regulate temperature settings. When the building is unoccupied, the thermostat set point can be reduced in the winter and increased in the summer, using less energy without sacrificing occupant comfort. Beforehand, set points for the thermostat during occupied times need to be established for each season to be both appropriate for occupant comfort and energy efficiency. The DOE suggests that during occupancy, a winter thermostat setting of 68°F and a summer setting of 78°F is good practice with the assistance of a programmable thermostat. Also, the thermostat should have a programmed setting for unoccupied periods. The DOE recommends a setback/setup of 10-15°F to save approximately ten percent a year on heating and cooling bills compared to a system without setbacks (Department of Energy, 2011b). If the controls are pneumatic, the thermostat most likely will not have the capability of programming. Therefore, to help save energy with this control type, a responsible staff member or trained occupants would have to manually correct the thermostat set point for both occupied and unoccupied situations. If a building automation system (BAS) exists, the programming could be adjusted to reflect the temperature settings defined above, or as an investment, a BAS system could be installed, which would incorporate thermostat controls, as well as all other system controls, such as exterior lighting, mechanical systems, and plumbing.

Lighting and Power Systems

This subsection details the importance of focusing on lighting and electrical deficiencies in educational buildings.   "For most school buildings, electric lights are the largest energy consumer (Department of Energy, 2007)." For example, about forty percent of school building energy usage is strictly for electric lighting (Department of Energy, 2007).

Therefore, energy-efficient lamps should be utilized for both interior and exterior applications. Specifically, incandescent lamps should be replaced with more efficient lamp options (compact fluorescents, LEDs, LED exit signs, etc.), and inefficient linear fluorescents should be replaced with more efficient linear fluorescent lamps.

For light fixtures that utilize incandescent lamps, compact fluorescent lamps are good replacements. In fact, buildings commonly convert incandescent downlights to fluorescent spot lights (with minor aesthetic differences) to realize recovered costs in less than one year with savings more than doubling over the subsequent three to four years (Zingale, 2005).

Additionally, linear fluorescent lamps are commonly used in educational facilities and are quite often T12s. As a reference, the following linear fluorescent lamps are listed in order of decreasing efficiency: T5HO, T5, T8, and T12s. Simply exchanging a T12 lamp with a T8 lamp can reduce energy consumption by approximately thirty percent, while maintaining the same light levels (Schultz, 2011). This is because a T12 lamp can only produce 70 lumens of light per Watt of energy whereas a T8 can produce 90 lumens per Watt (Knisley, 2003). Further improvement can be achieved when a T5 lamp is used because it can produce 100 lumens per Watt (Knisley, 2003). T5HO lamps were not suggested because they also produce 100 lumens per watt, but at almost twice the wattage as a normal T5 (Knisley, 2003), the T5HO would give more lumens than most rooms need. For example, if a T5HO lamp and T5 lamp were compared side-by-side, the T5HO would produce almost twice as many lumens as the T5, which makes it unsuitable for typical rooms. Usually T5HOs are utilized in high ceiling areas over twenty feet, to provide adequate light at the working surface.

Consequently, this report recommends that T12 lamps be replaced by T8 or T5 lamps, but if T8 lamps are in place, they do not need to be replaced. Moreover, linear fluorescents lamps cannot be directly exchanged with one another without at least changing the corresponding ballasts because the ballasts deliver power to fluorescent lamps. In many cases, it may be more advantageous to replace the entire fixture because the installation is less difficult and often has a lower initial cost than ballast replacement. Also noteworthy, a lamp's ballast continuously draws power whether the lamp is functioning or burnt out. Therefore, instead of intentionally not replacing lamps to save energy, instead, replace the fixture with one that has fewer lamps.

Another energy saving measure is to avoid over-lighting a building or individual room. A light level range of 30-50 footcandles is recommended for classrooms and offices according to the IESNA Guidebook Ninth Edition, while a gymnasium requires a higher light level, even up to 100 footcandles depending on the activities. If the footcandle readings are above the recommended values, then essentially less light is necessary. This could be accomplished by removing lamps and their associated ballasts or by removing a light fixture. If lamps are being removed, building managers need to pay attention to the uniformity of light being produced in the space to maintain a workable space for occupants. By avoiding over-illuminated spaces, occupants can remain productive at the recommended lighting levels and reduce electricity usage.

Another energy saving proposal is to install light management equipment, including dimmers, time clocks, occupancy sensors, and photocells to monitor occupancy and ensure the switching on/off of lights. For building exteriors, similar systems can be installed, such as time clocks or photocells, to read the amount of daylight.

Lighting controls should be upgraded also, even if the existing lamps are efficient. The first option is to install occupancy sensors in spaces (classrooms, offices, gymnasiums) that are frequently unoccupied to maximize potential savings, by ensuring that the lights are turned off when the spaces are not occupied. Occupancy sensors can save 35-45% of lighting energy costs (DiLouie, 2008). The second option is to install a time clock system that will automatically turn lights on and off in designated areas at predetermined times. This will ensure that the lights are not left on overnight or on the weekends. Both control options will reduce energy consumption; therefore, facility managers could choose either system, depending on personal preference or financial feasibility. To help offset the cost of lighting controls, many energy companies offer rebates per state based upon the controls being installed. The rebate information can be accessed through the DOE website or directly from the energy provider (U.S. Department of Energy, 2012b).

Daylighting is another aspect to consider; taking advantage of natural light can reduce electric light consumption considerably and radiant heat, which lowers the building’s cooling demand. “The savings can be as much as 10%—20% of a school’s cooling energy use (Department of Energy, 2007).” Also, utilizing daylighting during the day when the electricity rates are at their peak will save operating costs. To take advantage of natural lighting would require a photocell sensor to monitor the incoming daylight, and the existing lights would need to be reconfigured with dimming ballasts and rewired to connect to the photocell. The dimming would modulate the actual electrical light being produced to defer to mostly natural light when possible. Not only does daylighting increase efficiency in buildings, but it has also indicated enhanced student performance (Department of Energy, 2007).

Finally, appliance management and acquisition is one of the simplest adjustments. When equipment operation is not required, manually shutting it down will reduce a lot of unnecessary power usage. Items that could be shut down at the end of the day may include fans and personal equipment, such as computers and printers. Also, when choosing equipment to install, focus on selecting Energy Star certified equipment, which is indicated on labels affixed to equipment and appliances. There is a scale provided to rate the item in regards to others like it; therefore, try to select equipment with above average energy efficiency. Examples of Energy Star items include, but are not limited to, furnaces, water heaters, refrigerators, computers, and printers.

Building Envelope

The following subsection details the common energy deficiencies with building envelope assemblies and possible buildings, which are organized into no-to-minimal renovations and significant initial investment options.

The building envelope is one of the largest sources for heat loss/gain. To reduce heat loss/gain, a building needs to increase the tightness of its construction or add insulative material to reduce the amount of infiltration, which makes the mechanical system work harder to maintain temperatures within the space and makes it nearly impossible to control building moisture levels. First, weather stripping, sealant, or caulk should be installed on all windows and doors where existing sealant is ineffective to reduce infiltration. Furthermore, caulk or sealant should also be installed around building seams, walls, ceilings, and any other exterior joints that need to be resealed.

Another modification is to install exterior shading, either permanent or movable. This application would be best if daylight is not being harvested to supplement lighting, since it diminishes the entering rays. With shading, the solar heat gain is reduced and glare is minimized; however, the shading might detract from building aesthetics. Nevertheless, the reduced solar heat gain will allow the cooling demand to decrease, thus saving power through the mechanical system. To further decrease solar heat gain, consider using light-colored materials or paint for exterior walls and roofs to reflect solar rays (Department of Energy, 2007). However, in a Northern climate, the solar heat gain offsets the dominant heating load. Therefore, shading would not be recommended in Northern climates.

Next, all single-pane windows should be replaced with double-pane windows to reduce heat gains and losses. Based on Tables 5.5-1 through Table 5.5-8 in ASHRAE Standard 90.1-2010, the shading coefficient, or thermal insulating performance, for all vertical glass assemblies and skylights can be determined based upon the city's climate zone. The maximum U-value or the amount of heat transfer as a result of conduction for all glass can also be determined by the climate zone (ASHRAE, 2010). After determining the minimum solar values, then select the appropriate window and door properties, including thermal films, for a new assembly.

Insulation would also be a prime modification to consider. Enhancing the mass and insulative properties of an exterior surface reduces heat gain/loss, thus making the mechanical demand lower. Insulation can be added to an existing wall by several methods, for example, applying spray-in insulation for frame walls or furring out walls that cannot be accessed, such as masonry or concrete walls.

HVAC Systems

The following subsection details the common inefficiencies with mechanical system equipment and controls that waste energy. The information gathered with the audit form in Appendix B will help guide the auditor to finding those inefficiencies. By documenting the manufacturer, model number, fuel source, etc., the auditor can compare the mechanical equipment to recommended baseline equipment in ASHRAE Standard 90.1-2010 Section 6, and determine what action to take.

Moreover, a few minor changes to the mechanical system can save energy with no-to-low capital investment. The first item is to ensure that regular maintenance is performed on mechanical equipment, including changing air filters and cleaning coils. Another simple modification is to ensure that all fan belts are in proper tension and in good condition.

When possible, incorporate an economizer control scheme to optimize ‘free’ cooling/heating (Erickson, 2010) by bringing 100% outdoor air into the cooling system and so reducing work done by the cooling coils and premitting supply air to be cooled by indirect evaporation. In this way, 100% of the cooling load occurs at outdoor temperatures. If such a cycle is required, as determined in Section 6.5.1, Sections 6.5.1.1 and 6.5.1.2 from the ASHRAE Standard 90.1-2010 detail the minimum requirements for air and water economizers and controls (ASHRAE, 2010).

Variable frequency drives (VFDs) are another aspect of HVAC energy management that compensate for the constant operational speeds of fans and pumps in most older facilities where, in fact, heating and cooling loads are often not constant. The VFD is able to match the system capacity to the actual load throughout the entire year, allowing for energy to be saved rather than squandered.

Another energy saving measure would be to install demand-controlled ventilation based on occupancy. Traditionally, outdoor air is brought into buildings to satisfy the health requirements of occupants, for which designers must assume the space is at full occupancy.

However, the occupancy may frequently be less than this maximum; therefore, the system brings in more outdoor air than required and in turn uses more energy than required. Ventilation controls, when tied to occupancy counters/carbon dioxide monitors, can modulate the quantity of outdoor air accordingly. Installing this equipment has the potential for operational energy savings of $0.05 to $1.00 per square foot annually with the highest payback being expected in high-density spaces where occupancy is variable (Federal Energy Management Program, 2012).

ASHRAE Standard 90.1-2010 Section 6 contains all of the energy efficiency requirements for HVAC systems, and the section must be consulted to ensure energy code compliance for major building renovations. Within ASHRAE Standard 90.1-2010 Section 6, there are many guidelines to conserve energy including, kitchen and laboratory hood exhaust controls, energy recovery ventilators, new equipment minimum requirements, and overall system balancing (ASHRAE, 2010).

Plumbing System

The following subsection details the common inefficiencies of plumbing system components, which, if addressed could save energy and water savings. Information gathered with the audit form in Appendix B will help guide the auditor to find those inefficiencies. By documenting the manufacturer, model number, fuel source, etc., the auditor can compare the water heating equipment to recommended baseline equipment in ASHRAE Standard 90.1-2010 Section 7, and determine what action to take.

Existing plumbing fixtures are often above the enforced maximum flow rates for brand new fixtures, and therefore they consume much more water than newer fixtures. To ensure water consumption savings, install efficient, low-flow, low-water consuming plumbing fixtures. From the Energy Protection Act 2005, the flow rates for public fixtures are to be a maximum of 1.6 gallons-per-flush (GPF) for water closets, 0.5 gallons per minute (GPM) for lavatory faucets, and 1.0 GPF for urinals. The lower the fixture values of GPF or GPM, the lower the quantity of water consumed, and the higher the savings in water utilities. By trading conventional fixtures for low-flow fixtures, designers can save around thirty percent of water consumption annually (Department of Energy, 2007). Flow control devices can be installed on the lavatory faucets to ensure the maximum flow rate is not exceeded. Additionally, the water discharge temperature should be decreased to a maximum of 110 degrees Fahrenheit for public use lavatories, showers, janitor sinks, and kitchens, per ASHRAE Standard 90.1-2010, to reduce energy consumption and eliminate the risk of scalding (ASHRAE, 2010). If there is a recirculation line and pump system, the piping needs to be insulated per Table 6.8.3 in ASHRAE Standard 90.1-2010, and the controls need to be able to limit operational hours of the recirculation pump (ASHRAE, 2010).

To help save energy with pools, ASHRAE Standard 90.1-2010 Section 7.4.5–Pools describes two energy conserving means. Pool heaters should have a readily accessible on/off switch to allow for the heater to be shut off without adjusting the thermostat (ASHRAE, 2010). Also, if a pool is heated, then it should be equipped with a pool cover to help the pool retain its heated water temperature (ASHRAE, 2010).

Another water-saving modification would be to use native vegetation in any landscaped areas to eliminate irrigation water usage (Erickson, 2010). For educational facilities, an alternate option for traditional sprinkler irrigation on athletic fields, playground areas, or entrance landscaping, is to utilize high efficiency irrigation technology, such as drip irrigation. Another consideration is to irrigate only the athletic fields, rather than all the green-areas around the campus.

A plumbing alteration that might have a higher initial cost is to replace water heaters with those sized for realistic daily use, using an accepted method from the American Society of Plumbing Engineers (ASPE), ASHRAE, or manufacturer sizing calculators. ASHRAE Standard 90.1-2010 Section 7, details new equipment efficiency, piping insulation, and control systems for water heating systems (ASHRAE, 2010). Instantaneous water heaters are not always practical due to the building’s water demand, but they are more energy-efficient because they generate no stand-by losses attributed to the hot water being generated and stored for long periods of time. However, changing a water heater to point of use indicates any recirculation pumps associated with the old system be removed, allowing for additional energy savings. Furthermore, implementing an instantaneous water heater affects the electrical system. The breaker size and the wire size for the new equipment will have to be quite large because of the energy required to instantaneously create hot water. The additional electrical work will also increase the initial cost of exchanging the water heaters.

Another method to save water is to modify plumbing systems to reuse the building water or rain run-off. For example, irrigation water could come from a gray water system tied to the building’s lavatories or from a roof-water collection system.

Occupant Behavior Changes

Many physical building modifications can reduce energy consumption, but the users of the building also play a large role in conserving energy. "Carrying out operational strategies and enforcing them consistently encourages faculty, students and other user groups to reduce energy consumption in schools (Erickson, 2010)." First, the users must be knowledgeable about the energy-management system in the building and be able to operate it effectively. The energy management system could include turning off lights in spaces when they are not occupied, keeping vestibule doors closed, using energy-efficient appliances, turning off computers in the evening, and being conscious about water usage (Erickson, 2010). Next, a maintenance schedule for cleaning and servicing equipment is in order for, air-handling-unit coils, boilers, and furnaces, for example. Keeping the equipment clean will ensure that it is running smoothly and at peak performance. Also, fan rooms, boiler rooms, chiller rooms, and other mechanical rooms should be inspected periodically to ensure the same level of cleanliness. When users are aware, they tend to reduce energy consumption, thus saving building operational costs. While items within the buildings can be modified to alter energy consumption, altering use patterns is a primary way to reduce energy use (Erickson, 2010).

Chapter 7 - Cost Analysis

To justify improvement cost and determine what changes to schedule and finance first requires calculating economic analyses for each. There are two calculation methods: net present cost (NPC) and payback period. The lower the NPC, the less the modification will ultimately cost while the payback period reflects how quickly the item will begin saving money and returning the initial investment. The payback period also designates the time before an item pays back the initial capital with its energy and utility savings.

This study calculated the life-cycle cost to analyze possible building modifications using NPC, which allows for similar items to be compared for decision-making. To calculate the NPC of each proposed alteration, the first cost and annual maintenance cost for the life-cycle were calculated using traditional economic formulas. Specifically, the study used the 2011 RS Means Cost Data manuals to find the average initial, operating, maintenance, salvage, and demolition costs. Appendix D, Tables D-1 through D-4, shows the values for selected items corresponding to common building modifications. The study also assumed an interest rate of 6% and a life-cycle of 20 years (Newman, 2011). Equation 7-1, also in Appendix D, gives the formula for calculating NPC, followed by the definitions of the individual terms within the equation. Finally, equations 7-2 and 7-3 are needed to fully calculate equation 7-1.

Equation 7-1 Net Present Cost Equation (Newman, 2011)

$$\begin{aligned} \boldsymbol{NPC} = {} & (\boldsymbol{Item's First\ Cost}) + (\boldsymbol{Annual\ Maintenance\ Cost})(\boldsymbol{P|A,i,n}) \\ & + (\boldsymbol{Annual\ Energy\ Cost})(\boldsymbol{P|A,i,n}) + (\boldsymbol{Demolition\ Cost})(\boldsymbol{P|F,i,n}) \\ & - \boldsymbol{Salvage\ Cost} \end{aligned}$$

Net Present Cost Definitions:

- Item’s First Cost: Initial investment for the item.
- Annual Maintenance Cost: Cost to perform annual maintenance on the item.
- Annual Energy Cost: Cost to annually operate the item.
- Demolition Cost: Cost to remove an item after its lifespan is over.
- Salvage Cost: Worth of an item after its lifespan. (Ex: Selling parts back)

Equation 7-2 Present Cost Given Annual Cost Equation (Newman, 2011)

$$(P|A,i,n) = A * \frac{(1+i)^2 - 1}{i(1+i)^n}$$

- A: Annual Costs
- i: Interest Rate
- n: Number of Years

Equation 7-3 Present Cost Given Future Cost Equation (Newman, 2011)

$$(F|A,i,n) = F * (1+i)^n$$

- F: Future Costs
- i: Interest Rate
- n: Number of Years

After the NPC is determined, the payback period should be calculated by comparing the existing building component with a recommended replacement item. For example, the payback period, see Equation 7-4, might compare replacing existing incandescent lamps with new CFL lamps. The difference in initial costs is divided by the difference in annual energy costs, resulting in years to payback.

Equation 7-4 Payback Period Equation (Newman, 2011)

$$Payback\ Period = \frac{|\Delta\ P|}{\Delta\ A} = \frac{|Difference\ in\ Initial\ Costs|}{Difference\ in\ Annual\ Energy\ Costs}$$

The following example shows how to apply the equations in an economic analysis by comparing the economic validity of replacing an incandescent lamp with a compact fluorescent lamp. The values in the example came from the 2011 RS Means Cost Data manuals.

Table 7-1 NPC Incandescent and CFL Example

	Incandescent Lamp, 100W	Compact Fluorescent, 25W
First Cost	\$ 0.00	\$ 7.19
Annual Maintenance	\$ 2.29	\$ 2.29
Annual Energy Cost	\$ 23.36	\$ 5.84
Demolition Cost	\$ 5.00	\$ 5.00
Salvage Cost	\$ 0.00	\$ 0.00

Assumptions:
Interest Rate: 6%
Lifespan: 20 years
Electricity: Assumed rate of $0.07 kWh. Use regional applicable rate.

Equation 7-5 NPC Incandescent Example Calculation

$$NPC = (\$0.00) + (\$2.29)\left(\frac{(1+0.06)^2 - 1}{0.06 * (1+0.06)^{20}}\right) + (\$23.36)\left(\frac{(1+0.06)^2 - 1}{0.06 * (1+0.06)^{20}}\right) + (\$5.00)((1+0.06)^{20}) - \$0.00 = \$310.24$$

Equation 7-6 NPC CFL Example Calculation

$$NPC = (\$7.19) + (\$2.29)\left(\frac{(1+0.06)^2 - 1}{0.06 * (1+0.06)^{20}}\right) + (\$5.84)\left(\frac{(1+0.06)^2 - 1}{0.06 * (1+0.06)^{20}}\right) + (\$5.00)((1+0.06)^{20}) - \$0.00 = \$116.48$$

Equation 7-7 Payback Period Example Calculation

$$Payback\ Period = \frac{|\Delta\, P|}{\Delta\, A} = \frac{|(\$0.00 - \$7.19)|}{(\$23.36 - \$5.84)} = 0.41 \text{ years}$$

The economic analysis shows the NPC and payback period for replacing an incandescent lamp with a CFL lamp of comparable light output. The NPC clearly shows that the CFL is the better choice because it reflects a much lower value ($116.48) than the NPC of the incandescent lamp ($310.24). Also, the payback period is only 0.41 years, indicating that the initial costs of the CFL will be recovered relatively quickly by annual energy savings. The initial cost of the incandescent lamp is set to $0.00 because the lamp already exists and would not have to be purchased.

To make feasible recommendations for any educational facility, the NPC and payback period values must be taken into account. Once these values are calculated for the possible improvements, the similar options must be compared to determine the best financial options. To better understand what the calculated values indicate requires following a few guidelines. For example, the lower the NPC, the lower the overall cost of the item over its lifespan; meanwhile, the payback period depicts how long is required to recover the cost in years. For multiple options, select the item with the lowest NPC as well as the lowest payback period. If an item does not have the best value in both calculations, then the organization must decide which aspect is more important – overall cost, or recovering costs.

Economic analyses can be performed on all building components as long as data is available for initial costs, maintenance costs, energy costs, demolitions costs, and salvage costs. Appendix D has more example calculations displaying the NPC and payback period for some common building deficiencies found in energy audits in educational facilities. The following chapter, Chapter 8—Energy Audit at John Paul II Catholic Elementary School, outlines the audit process, including deficiencies found, economic analyses, and recommendations to help the school save energy.

Chapter 8 - Energy Audit at John Paul II Catholic Elementary School

The John Paul II Catholic Elementary School, located in Overland Park, Kansas, was constructed in three phases, and is essentially a building with three wings. The original building was built in 1944, the first addition was then added in 1954, and the next was added in 1964. The techniques and construction methods were kept fairly consistent throughout, thereby allowing energy efficiency recommendations to apply across the entire facility. However, analysis of the building showed many examples of energy inefficiency. The chapter will begin by detailing the building's utility usage. Next, the chapter will describe some of the building deficiencies the audit revealed followed by an analysis of the findings, and finally, the chapter gives recommendations to address the particular inefficiencies. The audit in its entirety is in Appendix A.

Utility Data Analysis

First, the utility data for water (WaterOne), natural gas (KGS), and electricity (KCPL) were analyzed. The best way to visualize the usage data is to create graphs to demonstrate usage trend, so Figures 8-1, 8-2, and 8-3 show water, natural gas, and electricity consumption, respectively. Next, the data were analyzed to reveal any outlying information that required further investigation. The data collected represents one year of usage, which displays utility usage comprehensively, but when possible, multiple years of utility data will more concretely depict usage trends.

Figure 8-1, the water consumption graph, readily shows that typical water use during the school year (late-August to mid-May) was very consistent and only slightly varied. Therefore, one would assume that water usage would greatly decrease during the summer months, since the children are no longer in school; however, the utility bills showed the opposite. The summer months registered a very large increase in water consumption, begging the question why. Consultation with the school staff revealed that the cause was new grass being watered during an atypically hot summer.

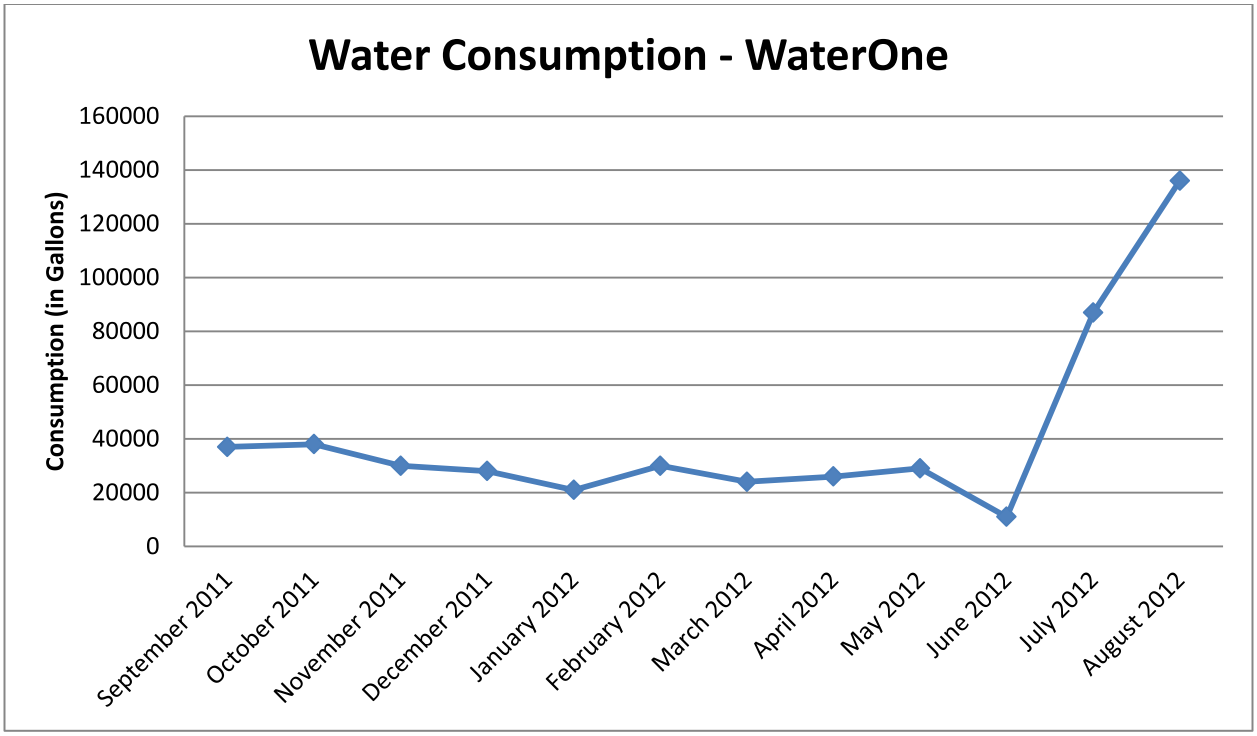


Figure 8-1 John Paul II Water Consumption

Next, the natural gas consumption, depicted in Figure 8-2, was analyzed. To be able to properly analyze the utility usage requires knowing what to expect. For instance, one assumption is that consumption peaks over the winter/heating months due to natural gas heating and dwindles to near zero in the summer/cooling months. As expected, the figure shows natural gas begins to be used more in mid-October, peaks in January, and then dwindles in mid-March. This finding raises no red flags that warrant further analysis.

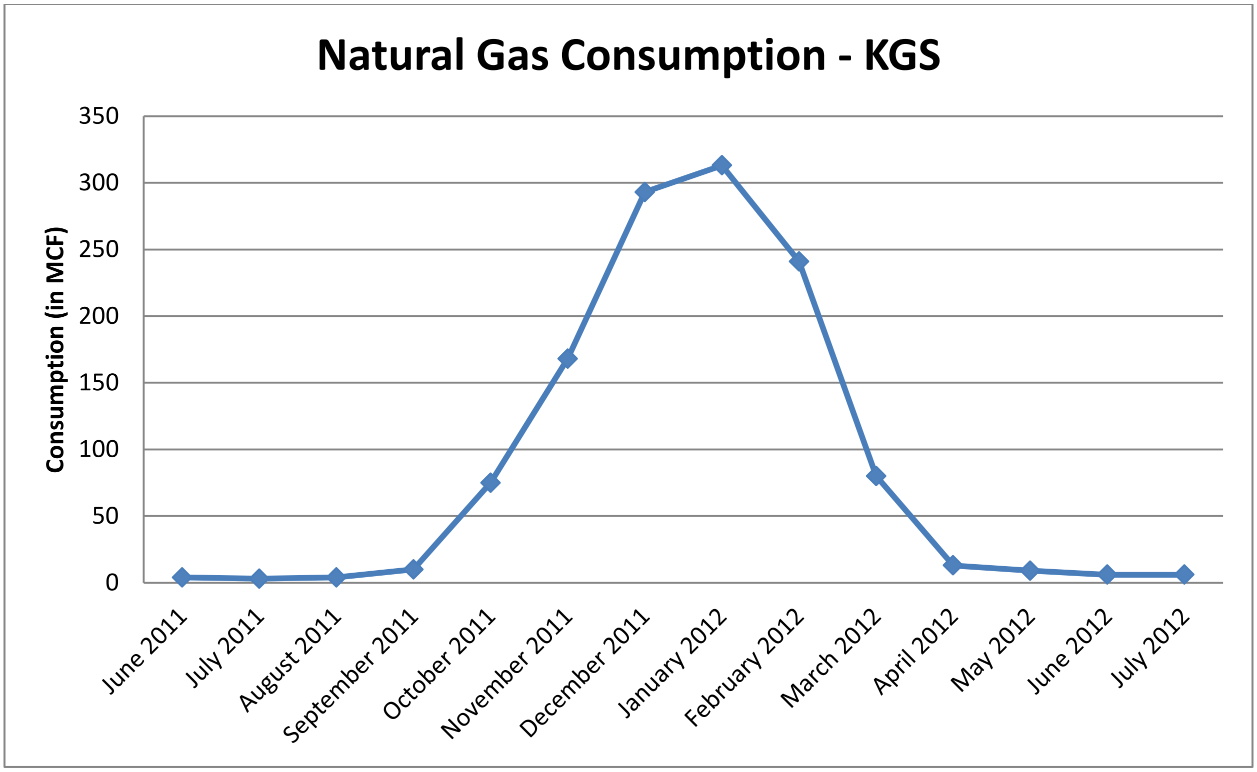


Figure 8-2 John Paul II Natural Gas Consumption

The last utility to analyze is electricity. First, assumptions from experience will determine if any data is unusual. With electricity, one would assume greater usage over the school year versus the summer months and greater consumption in the summer/cooling months as opposed to the winter/heating months. On the chart, two black vertical lines represent the school months of the year to help emphasize patterns. Also, the red vertical line represents when the mechanical system switched from cooling to heating. The graph shows the first two data points represent summer electricity use and fall below the data points for usage during school. This first finding meshes with initial consumption expectations and can therefore be considered normal. The next item to analyze is electricity during school months for which electricity usage was assumed to be greater in the summer/cooling months (before the red line) than in winter/heating months (after the red line), and as the graph shows, the data usage matches these assumptions. The winter/heating months do show electricity usage, but that is attributed to lights and powering equipment. Then, the months after the last black line represent the summer months. As expected, the first month dips to correlate with less energy used; however, the next two months show increased use, which raises the question why. In response, the school staff said that in the months leading up to the opening of school in August, much work was being done. Thus, the school had higher summer occupancy than predicted, due to preparations for the upcoming school year. Also, when compared to the unusual water usage in Figure 8-1 those two months correlate and can further support the claims about unexpected utility usage.

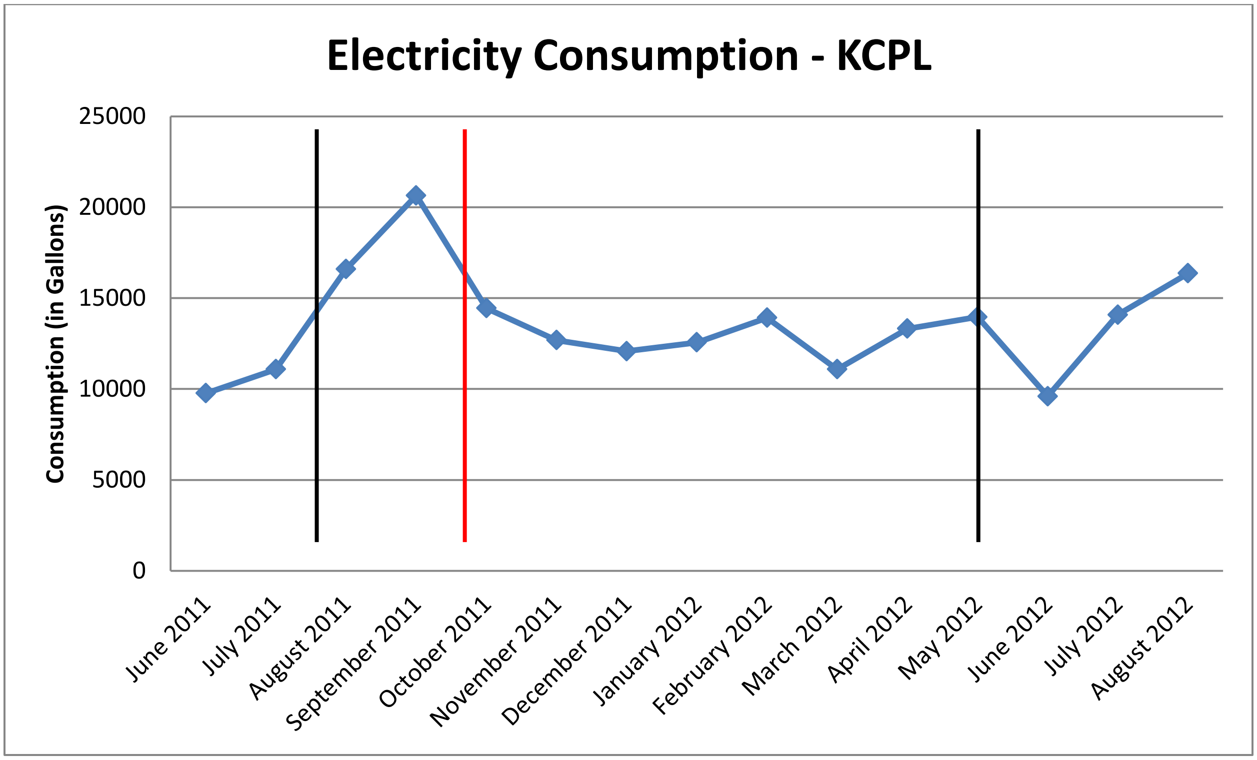


Figure 8-3 John Paul II Electricity Consumption

Building Energy Audit Analysis

After the audit was conducted, ASHRAE Standard 90.1-2010 was consulted, especially the items from Chapter 6–Common Deficiencies Identified by Audits, and the checklist in Appendix C to compare audit results to the minimum energy efficiencies set by the standard. That comparison yielded the following areas of concern, and these correlate with the energy efficiency guidelines this report endorses:

- Windows: (193) single-pane windows and hundreds of 6” x 6” glass blocks

- Lighting System: primarily T12 lamps utilized throughout the building, incandescent lamps, manual toggle light controls, daylighting, and window shading
- Building Envelope: exterior wall penetrations that allow infiltration
- Exterior Wall Construction: un-insulated exterior walls
- Kitchen equipment: high power-consuming equipment
- Plumbing System: fixtures that consume excess water
- HVAC System: single point of control for mechanical system, window a/c unit efficiency, and boiler efficiency and controls
- Behavior Modification

Audit Results Analysis and Recommendations

Compiling the data from the site visit into the whole building audit worksheets in Appendix A yielded the items listed in the prior subsection as building deficiencies and further analysis was required to determine economic feasibility of building modifications. Each of the following subsections discusses each building issue more completely, compares the component to the recommended baseline (ASHRAE Standard 90.1-2010), performs economic analyses, and then proposes solutions.

Windows

The first item requiring analysis was the 193 single-pane windows, which have an average U-value, or insulative value, of 0.90 (National Fenestration Rating Council, 2005). The U-value measures the ability to prevent heat from escaping a building in the winter and cooling from escaping in the summer. The lower the U-value, the better the window is at insulating (National Fenestration Rating Council, 2005). As a comparison, double-pane windows have an average U-value of 0.30 (National Fenestration Rating Council, 2005). Therefore, single-pane windows allow for more heat transfer and thus more energy to maintain a desired internal space temperature. ASHRAE Standard 90.1-2010 states the allowed U-value in Section 5—Building Envelope, which contains requirements for walls and windows per climate zone. John Paul II Catholic Elementary School’s location in Johnson County, Kansas, puts it in climate zone 4, which, in Table 5.5-4 in the standard, allows a maximum U-value for windows of U-0.55

(ASHRAE, 2010). Therefore, single-pane windows do not meet the requirements of ASHRAE Standard 90.1-2010.

Table 8-1 analyzes the heat loss associated with a single-pane window versus a double-pane window, showing a vast difference in thermal properties. This is because single-pane windows have U-values averaging around 0.90, while double-pane windows are closer to 0.30. Applied to typical classroom window dimensions of 3’0”x 3’0”, a heat loss equation shows that a single double-pane window is 66.7% better at conserving energy than a single-pane window.

Table 8-1 Heat Loss Window Calculations

Heat Loss Equation: $Q = U*A*\Delta T$		**Single-Pane Windows**	**Double-Pane Windows**
U : U-Value, Thermal Property, Btu/h-ft^2-F°		0.90	0.30
A : Area, ft^2		9.0	9.0
ΔT : Heating Temperature Difference (Assumed Room Condition is 72°F and Outdoor Winter Temperature is 2.6°F based on ASHRAE Guidebook)		(72-2.6)	(72-2.6)
Q : Heat Loss/Gain, Btu/h		562.14 Btu/h	187.38 Btu/h
Percentage Better: (562.14 – 187.38)/(562.14) *100 = **66.7%**			

Therefore, the energy information from Table 8-1 enables annual energy costs to be calculated with a few minimal assumptions. First, the natural gas usage from the utility data shows that heating is utilized from October to March (six months) at a utility company rate of $4.00/dekatherm. (Cooling was not considered in the annual energy costs due because cooling would take place in the summer, when the building is minimally occupied.) The initial cost information in Appendix D, Table D-1 shows a new aluminum double-pane window costs $432.50. Therefore, as shown in Equation 8-1, the payback period for replacing a single-pane window with a double-pane window is 240.28 years. Clearly, such a long payback precludes any recommendation to change out the single-pane windows with double-pane windows if the existing windows are still functioning properly. Instead, single-pane windows should be replaced when they fail. (If a school building is occupied in the summer months, then cooling costs could be integrated into the energy costs, obviously lowering the payback period for a window.)

Table 8-2 Window Analysis

	Single-Pane Window	Double-Pane Window
Energy Usage (Table 8-9)	562.14 BTU/h	187.38 BTU/h
Conversion from BTUh to Dekatherms	0.00056214 DTH/h	0.00018738 DTH/h
Assumed Usage: Six months, five days a week, and 10 hours a day	0.675 DTH/year	0.225 DTH/year
Annual Energy Cost ($4.00/DTH)	$ 2.70	$ 0.90

Equation 8-1 Double-Pane Window Payback Period

$$Payback\ Period = \frac{|\Delta\, P|}{\Delta\, A} = \frac{|\$0.00 - \$432.50|}{(\$2.70 - 0.90)} = 240.28 \text{ years}$$

The next item to analyze is the 204 - 6” x 6” glass blocks, which are located in corridors and vestibule spaces to illuminate them. Further analysis shows the glass blocks are very thick, compared to a typical window, approximately three inches deep. Therefore, the U-value of the glass blocks is equivalent to the properties of a double-pane window, and they can be termed sufficient to meet the requirements of ASHRAE Standard 90.1-2010 (National Fenestration Rating Council, 2005 & ASHRAE, 2010).

Lighting System

With respect to lighting, the classrooms all had adequate light levels according to the IESNA Guidebook, ranging from 30 to 35 footcandles measured at the students’ desk height. To accomplish this light level, each classroom utilized fifteen light fixtures each with two T12 fluorescent linear lamps. The classrooms were typically 682 square feet (22’ x 31’) with thirty–34 Watt lamps, resulting in 1020 Watts per classroom and a LPD of 1.496 Watts per square foot. ASHRAE Standard 90.1-2010 states the maximum LPD for renovated individual classroom spaces to be 1.24 Watts per square foot (ASHRAE, 2010). Therefore, if the existing classrooms were to conform to the energy standard, they would need a 174W reduction per classroom. To reduce the wattage in a space, lamp quantities would have to be adjusted, but a facility manager ought to contact a design engineer prior to adjusting light levels to maintain the proper lighting required for educational spaces.

Even though the lighting levels are adequate for a learning environment, the lamps used to illuminate the space are inefficient. The linear fluorescent lamps are T12s and need to be upgraded to a more efficient lamp choice. Also, since July 2010, many of the ballasts associated with T12 lamps are no longer being produced, and the T12 lamp as of July 2012 is also being phased out of production (Green Savings Company, 2012). Notably, since lamps cannot be changed without at least changing the ballasts and in many cases the entire fixture, replacement may be the better option. Specifically, the ballasts deliver power to fluorescent lamps and are not interchangeable between lamp types. Therefore, either ballasts must be exchanged or a new fixture must be purchased. Finally, a lighting engineer would recommend trading out all of the fluorescent linear lamps in a space at one single time. This is because the light output of the new lamps might not match that of the existing ones, thus causing lighting level differences throughout a space.

The school had incandescent lamps in all small closets and spaces, eleven of which required updating. Replacing incandescents is also necessary since they too are being phased out, and by July 2014, all common types of incandescents will no longer be available (Sylvania, 2011). However, ballasts do not need to be factored for the CFL lamps to replace the incandescent lamps because CFL lamps have integral ballasts. Depending on budget constraints, lamps can be replaced immediately or as a lamp fails, since CFL lamps have a very comparable light output to that of incandescent lamps.

From a controls perspective, currently all lights are controlled by manual toggle switches, which require users to remember to turn off the lights. However, it is common for public spaces such as bathrooms, break rooms, and so on to have lights on throughout the entire school day. ASHRAE Standard 90.1-2010 discusses lighting controls in Section 9—Lighting, requiring that “each space enclosed by ceiling height partitions shall have at least one control device to independently control the general lighting within each space” (ASHRAE, 2010). The controlled lighting should have at least one control step between thirty and seventy percent using dual-level switching, an occupant sensor or a timer switch (ASHRAE, 2010) to permit conservative energy use.

The recommendation is to replace the existing linear T12 fixtures with T5 lamp fixtures and either to change the lamp ballasts to accept the new lamps, or replace the entire fixture. As Table 8-3 shows, the initial costs, energy costs, and associated classroom footcandles indicate that the initial cost for a single classroom of thirty T5 lamps is $165 cheaper than thirty T12 lamps, and that the annual energy savings would be $170. To exchange T12 lamps for T5 lamps would require, that the entire fixture be replaced, rather than trading ballasts. A cost-analysis generated from material and labor prices from the RS Means Cost Data manual, suggests installing a completely new fixture. Table 8-4 displays the initial cost for one fixture replacement versus ballast replacement. The economic analysis supporting replacing all fifteen T12 lamp fixtures in a single classroom to T5 fixtures is in Table 8-5, which assumes the fixture costs $109.50, as defined in Table 8-4. If all sixteen classrooms were retrofit, the net present cost to replace all of their light fixtures would be $84,280.80, with a payback period of 9.66 years.

Table 8-3 Cost and Illumination Comparison for a Single Classroom

	Lamps	
Factors	**T12**	**T5**
Initial Lamp Cost (30 lamps)	$ 666.00	$ 501.00
Annual Energy Cost (30 lamps)	$ 353.70	$ 183.60
Footcandles	30 footcandles	42 footcandles

Table 8-4 Fixture and Ballast Comparison

	Cost of Fixture Replacement	**Cost of Ballast Replacement**
Material Description and Cost	2’x4’ Pendant Fixture, (2) T5 Lamps $ 52.00	2-Lamp Ballast, (2) T5 Lamps $ 96.10
Labor Cost to Install	$ 57.50	$ 50.50
Total	$ 109.50	$ 146.60

Table 8-5 Linear Fluorescent Fixture Analysis for Single Classroom

Item	**Net Present Cost**	**Payback Period**
T12 Fluorescent Fixtures (15)	$ 5,577.30	Between T12 and T5 Fixture 9.66 years
T5 Fluorescent Fixtures (15)	$ 5,267.55	

It would be much more efficient to install CFLs in place of the eleven incandescent lamps counted in the audit to save energy. This is because a CFL uses less power than an incandescent, but it can equally illuminate a space. Incandescent and CFL light economic analyses are in Table 8-6.

Table 8-6 Incandescent and CFL Lamp Analysis

Item	Net Present Cost	Payback Period
Incandescent Lamps (11)	$ 3,412.64	Between Incandescent and CFL Lamps: 0.08 years
CFL Lamps (11)	$ 1,281.28	

Updating the lighting controls is another beneficial modification, especially if the lights are being replaced within the building. Based on fixtures with two T5 lamps, dual-level switching would apply well since T5s produce 40% more light per watt than T8 lamps. The dual-level switching allows one switch to control all of the “first” lamps, while a second, independent switch controls all of the “second” lamps. This control method would allow energy to be saved, since not all lamps would have to be turned on together, but this method does require more wiring to implement the switching. Also, for dual-level switching to work, each lamp must have its own ballast. The economic calculation for ballasts in Table 8-4 is for one single two-lamp ballast; therefore, additional cost would need to be factored in to account for two single-lamp ballasts.

Also, automatic controls could be installed to help turn off lights in unoccupied spaces. For example, occupancy sensors work very well in classroom applications. The sensor would note when someone enters, triggering the lights to turn on. Then once, the sensor no longer sensed movement for a set period of time, the lights would switch off.   Wall occupancy sensors that would replace toggle switches range from $30 to $130 with a simple payback of from 0.5 to 5 years, while ceiling mounted occupancy sensors range from $45 to $140 with a simple payback of from 2 to 6 years (Michigan Department of Labor & Economic Growth, 2007).

Another controls option is daylight harvesting, with a projected annual energy savings of 10-20% (Department of Energy, 2007). Most of the classrooms have large windows that are not currently shaded, so light pours into the spaces. Shading could prevent light from flooding the space but still allow daylight in, and daylighting controls could regulate the use of the “free” light. However, this would require photocells to monitor the incoming daylight levels and dimming ballasts on the fluorescent lights. Installing the wiring and dimming ballasts often has a high initial cost, but many states and lighting companies offer rebates to offset the cost.

Building Envelope

The audit noted a few specific wall penetrations caused by poor installation allowed outside air into the space. This infiltration causes the mechanical system to work harder to maintain the desired temperature set point, thereby increasing the energy required to operate the system.

For leaks from the exterior wall penetrations, the holes need to be sealed with caulk to eliminate air leakage and save energy costs. It was not feasible to track energy cost savings to linear feet in caulk; however, research from the Missouri Department of Natural Resources states that caulking "will usually pay for itself in energy savings within one year" (Division of Energy, 2010). Table 8-7 outlines the net present cost of different caulking options. From the three options, latex caulking with ¼" seams would be recommended, unless the gap exceeds ¼", due to the lowest NPC value.

Table 8-7 Caulking Analysis

Item	**Net Present Cost**
Latex Caulking (1/4"x1/4"x Linear Foot)	$7.89
Latex Caulking (3/8"x3/8" x Linear Foot)	$8.08

Exterior Wall Construction

The building was constructed when building construction methods were different from current techniques. For example, many portions of the building's exterior walls are built-up four-inch common face brick. Since the walls are not thick and have little insulation, the exterior rooms, mainly classrooms, have limited protection from outside temperatures, which force the heating and cooling system to work much harder. The U-value of the current wall is 0.764 Btu/h-ft^2-°F, whereas ASHRAE Standard 90.1-2010 requires a maximum U-value of 0.104 Btu/h-ft^2-°F (ASHRAE, 2010). To meet the energy code, the wall construction would need to be altered.

Alternatively, to improve the exterior walls' insulative value, one solution is to fur out the interior portion. This consists of applying wood framing to the inside of the walls to create a void for adding insulation. The traditional method would be to use 1”x 2” or 1”x 3” furring strips, and then fill the void spaces with rigid foam insulation. Once the insulation is in place, the framing could be covered with drywall or paneling. Furring out the wall reduces the amount of heat gain/loss and meets the requirements of ASHRAE Standard 90.1-2010 as described further in this section, and occupant comfort is satisfied due to reduced drafts; however, a minor sacrifice is that the floor area of the original space would be minimally decreased.

The existing wall and proposed wall area and temperature difference values are simple to obtain, but the U-value must be determined. Using design data from the 2009 ASHRAE Handbook – Fundamentals generates a wall U-value derived from analyzing each component, finding the corresponding R-value, adding them all together, and arriving at the inverse of that value to create the U-value. For example, Table 8-8 displays how the U-value was created for the existing wall and the same wall with furring added.

Table 8-8 U-Value Calculations

Existing Wall		**Proposed Wall**	
Component	**R-Value from Table 5-15**	**Component**	**R-Value from Table 5-15**
Outdoor Air	0.17	Outdoor Air	0.17
Brick	(1/6) (2.75)	Brick	(1/6) (2.75)
Indoor Air	0.68	1”x3” Furring Strips	(3) (1.00)
R-Total	1.308	R-12 Insulation	10
U-Total (1/R)	**0.764 Btu/h-ft^2-F°**	1/2” Gypsum Board	0.45
		Indoor Air	0.68
		R-Total	14.758
		U-Total (1/R)	**0.06776 Btu/h-ft^2-F°**
R-Values source: (American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2009).			

Having a U-value permits the heat loss calculation using the same typical classroom exterior wall layout with seven – 3’x3’ windows and wall dimensions of 12’x 24’. Table 8-9 contains the calculation and displays how the proposed wall with furring is 91.1% better than the existing wall at conserving energy.

Table 8-9 Heat Loss Wall Calculations

Heat Loss Equation: Q = U*A*ΔT		**Existing Wall**	**Proposed Wall**
U : U-Value, Thermal Property, Btu/h-ft^2-F°		0.764	0.06776
A : Area, ft^2		225	225
ΔT : Heating Temperature Difference (Assumed Room Condition is 72°F and Outdoor Winter Temperature is 2.6°F based on ASHRAE Guidebook)		(72-2.6)	(72-2.6)
Q : Heat Loss/Gain, Btu/h		11,929.86 Btu/h	1,058.07 Btu/h
Percentage Better: (11,929.86 – 1,058.07)/(11,929.86) *100 = **91.1%**			

Next, to determine a payback period requires calculating, the initial cost to furr out the wall. Based on the 2011 Means Costs Data manuals, the initial cost to furr out the example wall of 225 ft^2 is $990.00, as described in Table 8-10. Therefore, the payback period, including reduced energy costs, is 18.98 years as calculated in Table 8-11 and Equation 8-2. This calculation is based on the assumption that heating is utilized from October to March (six months) at a utility rate of $4.00/dekatherm, based on the natural gas usage data.

Table 8-10 Furring Out Wall Cost

Item	**Cost/Unit**	**Price**
1” x 3” Furring Strips	$2.00/SF	$ 450.00
R-12 Insulation	$0.70/SF	$ 157.50
½” Gypsum Board	$1.20/SF	$ 270.00
Finish - Paint	$0.50/SF	$ 112.50
Total:		**$ 990.00**

Table 8-11 Furring Out Wall Payback Period

	Existing Wall	**Proposed Wall**
Energy Usage (Table 8-9)	11,929.86 BTUh	1,058.07 BTUh
Conversion from BTUh to Dekatherms	0.011930 DTH/hr	0.001581 DTH/hr
Assumed Usage: Six months, five days a week, and 10 hours a day	14.308 DTH/year	1.270 DTH/year
Annual Energy Cost ($4.00/DTH)	$ 57.23	$ 5.08

Equation 8-2 Furring Wall Payback Period

$$Payback\ Period = \frac{|\Delta\ P|}{\Delta\ A} = \frac{|(\$0.00 - \$990.00)|}{(\$57.23 - \$5.08)} = 18.98 \text{ years}$$

Kitchen Equipment

School kitchens have many pieces of energy-using equipment. Specifically, the kitchen of John Paul II Catholic Elementary School contained an exhaust hood fan, a carafe warmer, a ten-burner stove, a booster water heater system, three ovens, a pan warmer, five refrigerators, and a mixer. The best way to conserve energy in kitchens is to choose energy-efficient equipment when the existing equipment fails. Choosing Energy Star rated equipment helps ensure that the equipment is efficient and will save energy.

Some ASHRAE Standard 90.1-2010 minimum requirements for kitchen-based items include the exhaust hood in Section 6.5.7.1—Kitchen Exhaust Systems, and the booster water heater in Section 10.4.2—Service Water Pressure Booster Systems (ASHRAE, 2010). To determine whether the kitchen exhaust hood meets the minimum requirements would require performance testing to measure the airflow rates and to demonstrate proper capture and containment performance (ASHRAE, 2010). For the service water pressure booster system, a pressure sensor would need to be installed to modulate the start and stop of pumps, no devices should be installed to reduce pressure, and the booster system pump must not operate when there is no service water flow (ASHRAE, 2010).

Plumbing System

From a plumbing standpoint, the fixtures installed are dated and not as efficient as they could be. The existing features include, 1.5 GPF urinals, 1.6 GPF floor-mounted water closets, and 1.5 GPM public lavatories, have flow and flush rates much higher than currently allowed by the Energy Protection Act 2005 for new fixtures. The allowed values for urinals, water closets, and lavatories are 1.0 GPF, 1.6 GPF, and 0.5 GPM, respectively (U.S. Department of Energy, 2005).

A method to ensure water consumption savings is to install efficient, low-flow, low-water plumbing fixtures. As stated in Chapter 6–Common Deficiencies Identified by Audits, the Energy Protection Act 2005 dictates what the maximum flow rates can be for newly purchased and installed public fixtures. The lower the flow value, the more water can be reduced, and the greater the utility savings. Table 8-12 displays the economic analyses for replacing the existing plumbing fixtures and the detailed calculation is in Appendix D, Tables D-13, D-14, and D-15. The NPC values look very large because of the long-life of the fixtures and the assumed annual water usage costs for twenty years. Calculating the payback period depended on the assumption that the building functions 180 days a year according to the U.S. Department of Education average school days, with all urinals and water closets receiving thirty flushes a day and every lavatory faucet running thirty minutes a day. The water utility rate used was an average rate of $4.02/1000gallons. With the payback period being fairly short, only the lavatory faucet would be a financially beneficial investment. The urinals and water closets suggest payback periods exceeding the life of the building and therefore cannot be justifiably replaced, especially since they are still functioning well.

Table 8-12 Plumbing Fixture Analysis

Item	NPC	Payback Period
Existing (8) Urinals: 1.5 GPF	$ 4,550.88	41.76 Years
Replacement Urinal: 0.5 GPF Wall-Hung	$ 8,207.00	
Existing (28) Water Closets: 1.6 GPF	$ 15,903.44	99.57 Years
Replacement Water Closet: 1.28 GPF Floor-Mount	$ 28,143.92	
Existing (14) Lavatory Faucets: 1.5 GPM	$ 7,133.42	4.05 Years
Replacement Faucet: 0.5 GPM	$ 2,959.32	

HVAC System

This subsection will cover the possible improvements for the HVAC system beginning with efficiency of the window air conditioning unit, followed by the boiler efficiency. The section will then list possible modifications.

Window A/C Unit Efficiency

The next item to analyze is the heating and cooling system where the current mechanical system does not provide much control. The cooling system includes window units in each classroom, which, while they provide limited cool air to a space and are noisy, do allow for individual thermostat space control. Currently, some of the window units meet the minimum efficiency requirements of ASHRAE Standard 90.1-2010 because they have been recently replaced. If the window units require replacement, they must meet the minimum efficiency requirement of 12.0 SEER, as stated in Table 6.8.1A in the ASHRAE Standard 90.1-2010 (ASHRAE, 2010).

Boiler Efficiency and Controls

The heating system consists of two boilers, each one serving half of the building. The boilers produce hot water to serve each of the perimeter radiators located within the building spaces. The first is an old fuel oil boiler that has been converted use natural gas. The efficiency of this boiler, by looking at the nameplate values of 1200 MBH output and 1500 MBH input, is 80%. However, retrofitting such boilers loses three to five percent efficiency (Faye, 1986). Therefore, the first boiler has an operating efficiency in the range of 75-77%. The second boiler is much newer and uses natural gas for its heat source. This boiler has an efficiency of 78.4% with 1433 MBH output and 1827 MBH input. ASHRAE Standard 90.1-2010 Table 6.8.1F, Gas- and Oil-Fired Boilers, Minimum Efficiency Requirements, defines the minimum efficiency for new gas-fired, hot water boilers of this capacity to be 80% (ASHRAE, 2010). If either of the boilers fails and needs to be replaced, they must be at least 80% efficient according to ASHRAE Standard 90.1-2010. For controls, both of the boilers are either on or off, based on the school calendar. To comply with ASHRAE Standard 90.1-2010, the heating system controls must comply with Section 6.4.3 within the standard, which means they must have zone thermostatic controls, automatic shutdown controls, and setback controls (ASHRAE, 2010). Options to improve the current mechanical system are discussed next in this section, along with the economic impact of the options.

Multiple options exist to improve the heating system, each with increasing initial investment expense, as well as more control options. The first option addresses the main boiler controls, more specifically when to turn them on and off. Currently, the boilers are either on or off, based on the calendar. The better option would be to control the boiler based on the outdoor air temperatures and to operate the boilers only when heating is required to meet the thermostat set points. To do this would require an outdoor air temperature sensor tied to a control system. The sensor would monitor the outdoor temperature and communicate with a control system connected to the boilers. The system would then control the on/off switch for the two boilers depending on the temperature. This first option has an initial cost impact of approximately $4,500.00 according to the 2011 RS Means Cost Data manuals, based on purchasing an outdoor air sensor and installing a control program at the boilers.

The second option deals with hydronic controls, which depend on thermostatic controls to increase the points of control throughout the building. ASHRAE Standard 90.1-2010 requires a thermostatic control in every zone, which is “a space or group of spaces within a building with heating and cooling requirements that are sufficiently similar so that desired conditions can be maintained throughout using a single sensor” (ASHRAE, 2010). For example, a zone could be a group of classrooms with a Northern exterior wall exposure. Currently, the building is set up in two zones, each zone being one half of the building. With the current set-up, the spaces being zoned together do not have similar enough heating requirements to warrant being on one thermostat control. The hot water flows through the loop system into each of the radiators and then returns to the two individual boilers to be reheated, but the recommendation would be for piping and valves to be installed before a room or zone that could communicate with a space thermostat. Depending on occupant thermal needs, the valves would open/close to modulate the water flowing through the radiators, thus regulating room temperatures. For this option, radiator valves would need to be added at each room or zone; furthermore, depending on the design and material, each valve could cost $97.50 (RS Means, 2011). Next, the valves mark areas of control, so each valve would need a space thermostat to control room conditions. The 2011 RS Means Mechanical Cost Data manual notes the material cost for a flow meter is $222, and for an automatic, 24-hour thermostat, it is $188.50. The renovation would also require additional costs such as draining and refilling the hydronic system, modifying wall construction, and connection/wiring of the thermostatic controls. Also, a mechanical designer would need to design the system and accurately project an installation cost. Further investigation could generate more options for the mechanical system; however, with an ASHRAE Level II energy audit, “bid-level construction cost estimating” is not incorporated as it is with a Level III, but rather, a Level II focuses on general costs. Therefore, a mechanical design engineer should analyze any other mechanical system renovations to ensure efficiency of the system, success of operation, and to accurately estimate a budget.

Occupant Behavior Modification

Conducting the building energy audit and consulting with some of the teachers has elicited a few behavior modification suggestions. The benefit to changing small occupancy behaviors is significant energy savings with no initial costs. Primarily, occupants need to be knowledgeable about the energy-management system in the building and must be able to operate it efficiently. The energy management system could include turning off lights in spaces when they are not occupied, keeping vestibule doors closed, using energy-efficient appliances, turning off computers in the evening, and being conscious about water usage (Erickson, 2010). Making users aware tends to result in reduced energy consumption. Certainly facilities features and equipment can be modified to alter energy consumption, but behavior is a main element in energy reduction (Erickson, 2010).

Chapter Summary

To summarize building audit analyses and economic information for the John Paul II Catholic Elementary School, Table 8-13 addresses the recommendations, with which the school facility could reduce utility usage and cost, increase occupant comfort, and ultimately increase energy efficiency. The items are listed in order of recommended implementation, based on initial investment and payback potential. Table 8-14 lists the possible building modifications that were also discussed in this chapter, but that are not being recommended for implementation because the payback period was too long, the equipment should be upgraded only when the existing part fails, the component was already efficient, or the systems would need a design engineer to better design the improvement and estimate the budget.

Table 8-13 Audit Recommendations Summary

Current Item/System	Recommendation/Modification	Payback Period/Savings
Energy-Management System	Train Occupants to Conserve Energy	Immediate savings
Incandescent Lamps	CFLs	0.08 years
Leaking Exterior Penetrations	Caulk/Seal Joints	1.00 year
T12 Fixtures	T5 Fixtures	0.97 years
Manual Toggle Switches	Automatic Lighting Controls	0.5 - 5 years
Outdated Plumbing Fixtures	Low-Flow Lavatory Faucet	4.05 years
Brick Walls, Minimal Insulation	“Furr-out” the Walls	18.98 years

Table 8-14 Building Modifications Not Recommended

Current Item/System	Recommendation/Modification	Payback Period/Savings
Outdated Plumbing Fixtures	Low-Flow Urinals	41.76 years
Outdated Plumbing Fixtures	Low-Flow Water Closets	99.57 years
Single-Pane Windows	Double-Pane Windows	240.28 years
Kitchen Equipment (Exhaust System and Water Pressure Booster)	Systems that meet ASHRAE Standard 90.1-2010 minimum requirements	n/a
6” x 6” Glass Blocks	N/A, Keep as is	n/a
Mechanical System with Minimal Controls	Window A/C Unit Efficiency, Boiler Efficiency and Controls	Requires a Mechanical Design Engineer to design system and outline installation costs

There are rebates and incentive programs available to help public buildings implement energy-efficient building components. For example, currently in Kansas, a utility loan program is currently available that helps finance energy efficiency improvements. The program is sponsored through Midwest Energy and can be accessed further at http://www.mwenergy.com/howsmart.aspx (U.S. Department of Energy, 2012b).

Chapter 9 - Future of Audits

With the continuous goal for buildings to consume less energy, discovering energy-saving means will continue to be very important. As this report has demonstrated, energy audits are an optimal method of uncovering energy reducing measures. Currently, energy audits are being performed somewhat at a pen-and-paper level with the guidance of audit workbooks, much like the one in Appendix B. However, the future of energy audits is expanding because more owners are demanding them, and to better accommodate these demands, energy audits need to become easier and more streamlined. In response, the DOE has developed software for lighting and electrical audits called "ecoInsight Energy Audit & Analysis Software." This software is free to download and "revolutionizes the way energy audits are conducted by providing professionals with mobile audit capabilities (iPad), integrated product pricing, and performance information and sales proposal generation tools (Department of Energy, 2011c)." The software works by allowing auditors to digitally collect information about building equipment, energy use, and occupant information with a mobile device. The collected information is then immediately available for analysis, collaboration, and proposal generation (Department of Energy, 2011c). The software has pre-loaded catalogs for which to select replacement equipment, thus enabling labor, maintenance, and operation cost savings. Also, reports can be generated quickly, especially when the items of concern are in a pre-loaded list. To utilize this software to the fullest potential, an individual within the school system would need to devote time to prepping the software, uploading the appropriate catalogs to match recommended upgrade items, and instructing the auditors on how to collect data and analyze the results. This report does not recommend using this software because it does not include all of the building systems, but instead primarily focuses upon the electrical and lighting systems (Department of Energy, 2011c).

Nevertheless, with advancing technology, energy audit procedures are going to become easier and quicker with software, which could reduce weaknesses such as human error and overlooking building information.

Areas Needing Further Development

After the energy audit based on the workbook in Appendix B, the compiled results led to building modification recommendations for reducing energy consumption. However, the audit did reveal weaknesses in the procedure tied to time and budget constraints. For instance, the window of time to perform the audit and the limited budget meant all data had to be collected by a single individual and then later input into the electronic worksheets. To help improve data collection accuracy and reduce time to complete an audit, technology seems the most logical answer. Also, the educational energy audit in Appendix A revealed the inability to compare data results to those of other educational buildings and the restriction of only one year of utility data to analyze. Having more educational facility experience and more than one year of data might have led to more recommendations.

Consequently, a future recommendation would be to perform additional audits on educational facilities and compare results and recommendations to perhaps generate greater energy efficiency. Examples of information types for audit comparisons are different building sizes (areas), different construction types, different occupancy schedules, and different years of construction.

Also, a monitoring plan should be set up at an individual facility to ensure that energy goals, such as utility usage, are being met over the life of the building. The monitoring plan could include recording and plotting monthly utility bills to look for patterns of increased usage, or to confirm that the building is continuing to save energy (ASHRAE, 2008). Monitoring utility data would also allow the owner to track the true savings attained by implementing the recommendations.

Chapter 10 - Conclusion

Educational facilities need to focus on saving energy and building operation costs to meet regularly reduced annual budgets, thus allowing more money to be applied to student education. Energy audits are a key way to identify energy-saving opportunities within facilities. In part this is because reducing energy consumption in buildings requires improving the efficiency of building components. Accordingly, the research in this report determined what code/standard should be referenced for minimum energy requirements, established an energy audit procedure, and outlined a path to discover recommended improvements for educational buildings.

To create a basis of energy efficiency, a baseline standard based on the determinations of the DOE and ASHRAE Standard 90.1-2010 was selected as the reference for minimum acceptable energy requirements. ASHRAE 90.1-2010 applies to all educational facilities, including new buildings and renovations to existing buildings. It also establishes requirements for all aspects of a building but specifically the building envelope, the HVAC system, the electrical and lighting systems, and the service hot water system.

With ASHRAE Standard 90.1-2010 as the minimum acceptable requirement, an energy audit procedure was created to survey buildings and to determine components that needed energy efficiency improvements. The report then outlined common energy audit findings and the results from an energy audit conducted at John Paul II Catholic Elementary School in Overland Park, KS. From the data collected during the audit, common deficiencies emerged that led to possible improvements to increase the efficiency of a facility.

Then, the NPC and payback period were calculated for each possible change to determine which improvements were feasible. The final recommended changes included training occupants to conserve energy, sealing all exterior penetrations, furring out and insulating the exterior walls, replacing lighting fixtures and lamps with more energy-efficient options, utilizing lighting controls, and installing low-flow plumbing fixtures.

Building managers can reference confidently the example energy audit performed at John Paul II Catholic Elementary School in Chapter 8 as it used the outlined audit procedure, analyzing the results and comparing them to a baseline, and determining a cost analysis. From the analysis came recommendations that included components from the building envelope, lighting system, plumbing system, and mechanical system.

Further recommendations include the continual auditing of educational facilities. For example, each facility should be audited once every couple of years to avoid or fix problems such as air leakage, burned out lamps, or equipment malfunction before they significantly affect the building's overall efficiency. The printable audit procedure, worksheets, and audit checklist in Appendix B should be used to audit each facility. Furthermore, using the resources in Appendix B and C, the individual(s) conducting the audit can determine changes to reduce the energy consumption of the facility. Next, the equations in Chapter 7 and Appendix D can generate the net present cost and payback period for the changes. The facility manager can then select viable changes based on the economic analyses. Finally, to offset building modifications costs, government agencies often offer rebates and incentive programs. For example, a tax deduction is available until December 31, 2013, for eligible efficiency technologies such as lighting controls/sensors, caulking/weather stripping, and building insulation (U.S. Department of Energy, 2012b).

To reach the projected energy savings will require investment that in turn will cause a significant positive impact long term. Naturally, such changes and improvements are gradual and depend on the continual cycle of auditing and improving in relation to the baseline. Moreover, in the future, a new baseline likely will need to be adopted as the construction industry, equipment availability, and energy codes evolve. Nevertheless, for now, this report contains the necessary tools to determine the minimum acceptable requirements for energy design, implement an auditing procedure, and determine the crucial and feasible changes to implement in educational facilities.

Bibliography

Alajmi, A. (2011). Energy audit of an educational building in a hot summer climate. Elsevier. 1-9.

American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2004). *Procedures for commercial building energy audits* (1st ed.). Atlanta, GA: ASHRAE.

American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2009). *ASHRAE handbook-fundamentals*. Atlanta, GA: ASHRAE.

American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2010). *Standard 90.1-2010 (I-P edition) – energy standard for buildings except low-rise residential buildings (ANSI approved; IESNA co-sponsored).* Atlanta, GA: ASHRAE.

Callahan, J. (2012, June 21). School district's utility bills continue to shrink. *Ocala*. Retrieved from http://www.ocala.com/article/20120621/articles/120629923

Department of Energy. (2007). *National best practices manual for building high performance schools.* Department of Energy.

Department of Energy. (2011a). *Building energy codes: Commercial determinations.* Retrieved from http://www.energycodes.gov/status/determinations.com.stm

Department of Energy. (2011b). *Thermostats and control systems.* Retrieved from http://www.energysavers.gov/your_home/space_heatin_cooling/index.cfm/mytopic=12720

Department of Energy. (2011c, September 14). *Building energy software tools directory*. Retrieved from ecoInsight Energy Audit & Analysis Software: http://apps1.eere.energy.gov/buildings/tools_directory

Department of Energy. (2012). *Building energy codes: Status of state energy codes.* Retrieved from http://www.energycodes.gov/states/

DiLouie, C. (2008, July). Occupancy sensors, intelligent control panels save energy. Retrieved from http://www.facilitiesnet.com/energyefficiency/article/Occupancy-Sensors-Intelligent-Control-Panels-Save-Energy--9151#

Division of Energy, Missouri Department of Natural Resources. (2012). *Residential energy efficiency - caulking and weatherstripping*. Retrieved from website: http://www.dnr.mo.gov/energy/residential/caulk.htm

ecoInsight. (2012). *Audit software - commercial energy audit*. Retrieved from http://ecoinsight.com/index.htm

Energy Audit Institute. (2010). *Energy audit guide*. Retrieved from http://www.energyauditinstitute.com

Erickson, P. W. (2010). Tracking costs. *American School & University , 82* (10), 22.

Fay, J. A., Golomb, D. S., & Zachariades, S. C. (1986). *Feasibility and cost of converting oil- and coal-fired utility boilers to intermittent use of natural gas*. Informally published manuscript, Energy Laboratory, Massachusetts Institute of Technology, Cambridge, MA, Retrieved from http://dspace.mit.edu/bitstream/handle/1721.1/27246/MIT-EL-86-009-18573189.pdf

Federal Energy Management Program. U.S. Department of Energy, Energy Efficiency and Renewable Energy. (2012). *Demand-controlled ventilation using co2 sensors*. Retrieved from http://www1.eere.energy.gov/femp/pdfs/fta_co2.pdf

Green Savings Company. (2012). *Legislation, lights out: T12 phase out.* Retrieved from http://greensavingsco.com/resources/legisaltion/

Kelderman, E. (2008). Budget picture for colleges is brighter than expected in many states. *The Chronicle of Higher Education , 54* (36), 23.

Knisley, J. R. (2003). The T5 fluorescent lamp: coming on strong. *Electrical, construction, and maintenance*, Retrieved from http://ecmweb.com/archive/t5-fluorescent-lamp-coming-strong

LG. (2012). *Window air conditioners*. Retrieved from http://www.lg.com/us/window-air-conditioners

Michigan Department of Labor & Economic Growth. (2007). Occupancy sensors for lighting control. *The energy observer: Energy efficiency information for the facility manager*, Retrieved from http://www.michigan.gov/documents/dleg/EO_12-07_218809_7.pdf

Mohammadi, H. (2009). Electricity prices and fuel costs: Long-run relations and short-run dynamics. *Energy Economics*, (31), 503-509. Retrieved from http://www.erasmusenergy.com/articles/179/1/Electricity-prices-and-fuel-costs-Long-run-relations-and-short-run-dynamics/Page1.html

National Clearinghouse for Educational Facilities. (2012). *School building statistics: Age of schools*. Retrieved from http://www.ncef.org/ds/statistics.cfm

National Fenestration Rating Council. (2005). *The facts about windows & heat loss*. Retrieved from http://www.nfrc.org/documents/U-Factor.pdf

Newman, D., Eschenbach, T., & Lavelle, J. (2011). *Engineering economic analysis*. (11th ed.). Oxford University Press.

Oliff, P., Mai, C., & Leachman, M. (2012, September 04). *New school year brings more cuts in state funding for schools*. Retrieved from http://www.cbpp.org/cms/?fa=view&id=3825

Phan, A. (2012, March 14). Maintenance, utility costs factor in north kitsap school closure discussion. *Kitsap Sun*. Retrieved from http://www.kitsapsun.com/news/2012/mar/14/maintenance-utility-costs-factor-in-north-kitsap/

RSMeans. (2011). *RSMeans mechanical cost data*.

Schultz, C. (2011). Energy conservation in existing buildings. Engineered Systems , 34-40.

Sylvania. (2011, June). *How many people does it take to change a light bulb?.* Retrieved from http://assets.sylvania.com/assets/Documents/CONSLEGIS-2010.4f30843d-1e56-4791-a827-8fd269771f3c.pdf

U.S. Department of Energy. (2012a). Commercial building initiative: Energy modeling software. Retrieved from http://www1.eere.energy.gov/buildings/commercial_initiative/modeling_software.html

U.S. Department of Energy. (2012b). *Database of state incentrives for renewables & efficiency.* Retrieved from http://www.dsireusa.org/summarymaps/index.cfm?ee=1&RE=1

U.S. Department of Energy. U.S. Department of Energy, Energy Efficiency & Renewable Energy. (2005). *Energy policy act of 2005*. Retrieved from website: http://www1.eere.energy.gov/femp/regulations/epact2005.html

U.S. Environmental Protection Agency. (2010, December 02). *Reducing energy use: Green homes.* Retrieved from http://www.epa.gov/greenhomes/ReduceEnergy.htm

US Fed News Service. (2008). Department of Environmental Protection, public utilities commission award energy audits, efficiency installations to schools. *US State News*.

U.S. Green Building Council. (2012). *USGBC: What LEED is.* Retrieved from http://www.usgbc.org/

Wah, W. Y. (2001, April 18). Energy audit for buildings. *BCA Seminar on Energy Efficiency in Building Design* . Singapore.

Washington State University, C. E. (2003). *Energy audit checklist.*

Washington University, C. E. (2003). *Washington State University energy program energy audit workbook.*

Wulfinghoff, D. R. (2000). *The modern history of energy conservation: An overview for information professionals.* Energy Institute Press.

Zingale, N. (2005). Considering an energy audit? Think payback. *Industrial Heating* , 18.

Resources

4-in-1 air velocity meter – anemometer, hygrometer, light meter, thermometer. Retrieved 5/3, 2012, from http://www.omega.com/ppt/pptsc_lg.asp?ref=hhf81&Nav=

Acoustical Society of America (ASA). (2002). *ANSI S12.60-2001: Acoustical performance criteria, design requirements, and guidelines for schools*. Melville, NY: ASA. Retrieved from http://www.trane.com/commercial/library/vol32_1/index.asp

AIA. (2012). *Status of state energy code adoption and compliance measurement*. Retrieved from http://www.energycodes.gov/publications/presentations/AIA_2010_presentation.pdf

American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2008). *Advanced energy design guide for K-12 buildings.* Atlanta, GA: ASHRAE.

American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2011). *Advanced energy design guide for K-12 buildings.* Atlanta, GA: ASHRAE.

American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2011). *Procedures for commercial building energy audits* (2nd ed.). Atlanta, GA: ASHRAE.

Bloomberg. (2012). *Energy & oil prices: Natural gas, electricity and oil.* Retrieved from http://www.bloomberg.com/energy/

Checket-Hanks, B. (2010). Energy audits in HVAC. *Air-Conditioning, Heating & Refrigeration News* , 8-10.

Conover, D. *Commercial energy codes: Where are we now and where are we going.* Retrieved from http://www.energycodes.gov/publications/presentations/CSI_presentation_091111.pdf

D'Antonio, P. (2004). Energy star, LEED, and commercial buildings. *HPAC Heating, Piping, Air Conditioning Engineering, 76*(5), B2-B12.

Energy Trust of Oregon. (2012, June 14). *Klamath county school district makes the grade in energy efficiency*. Retrieved from http://energytrust.org/news/news/120613_KlamathCountySchoolDistric_PR0.pdf

FLIR B series infrared thermal imagers. Retrieved May 3, 2012, from http://www.aikencolon.com/FLIR-B-Series-Infrared-Thermal-Imagers_c_1069.html

Franklin, B. (1984). Energy audits and information analysis. *Energy Management in Buildings.* 21-35.

Green Energy Parks Partnership. U.S. Department of Energy, Federal Energy Manmagement Program. (2001). *Lighting retrofit workbook.* Retrieved from http://epb.lbl.gov/publications/pdf/nps_guidebook.pdf

Hoshide, R. K. (1995). Effective energy audits. *Energy Efficiency: Journal of the Association of Energy Engineering*, *92*(6), 6-17.

Howell, R., Coad, W., & Sauer, H. (2009). *Principles of heating, ventilating and air conditioning*. (6th ed.). Atlanta, GA: ASHRAE.

Kennedy, M. (2010). Overcoming obstacles to going green. *American School & University , 82* (6), 14.

Krarti, M. (2011). *Energy audit of building systems: An engineering approach.* Boca Raton: CRC Press.

Lauderdale, M., & Wunderlich, J. R. (1984). Energy audits - common mistakes to avoid. *Specifying Engineer*, 52(1), 74-78.

Liu, B. (2008, February 07). Compliance with ASHRAE 90.1 and LEED. Retrieved from http://www.ashrae.bc.ca/vi/presentations/Compliance with ASHRAE & LEED (02-07-2008).pdf

Lutron. (2012). *Commercial energy savings sources*. Retrieved from http://www.lutron.com/Experience-Light-Control/Lutron/Documents/Commercial_Energy_Savings_Sources.pdf

Mcdonnell, P. (2005). Using standard 90.1 for energy savings and LEED credits. *HPAC Heating, Piping, Air Conditioning Engineering*, 77(2), 35-38.

Murphy, M. (2009). Energy audits coming into their own - again. *Air Conditioning, Heating & Refrigeration News* , 22.

Owens, B. (2010). LEED amp green building codes. ASHRAE Journal, 52(6), S6-S8.

Piper, P.E., J. (2009, November). *The benefits of vfds in hvac systems*. Retrieved from http://www.facilitiesnet.com/hvac/article/The-Benefits-of-VFDs-In-HVAC-Systems--11278

RSMeans. (2011). *RSMeans plumbing cost data*.

RSMeans. (2011). *RSMeans building construction cost data*.

RSMeans. (2011). *RSMeans facilities maintenance and repair cost data*.

Shapiro, I. (2011). 10 common problems in energy audits. ASHRAE Journal, 53(2), 26-32.

Stecky, N. (2005). Introduction to the ASHRAE GreenGuide for LEED: Strategic planning for energy and the environment, 25(1), 63-80.

The Energy Systems Laboratory Texas Engineering Experimentation Station Texas A&M University System. ANSI.ASHRAE/IESNA standard 90.1-2010 update & overview. Retrieved January 15, 2012, from http://www.seco.cpa.state.tx.us/tbec/docs/ASHRAE2010TrainingPresentation.pdf

Turner, W. C. (2005). Energy management handbook (5th ed.). Lilburn, GA: The Fairmont Press, Inc.

Wierzba, A. L., Morgenstern, M. A., Meyer, S. A., Ruggles, T. H., & Himmelreich, J. (2011). A study to optimize the potential impact of residential building energy audits. *Springer Science+Business Media* , 1-11.

Williams, J. (2012). *WTRG economics – OPEC, crude oil, natural gas, analysis, forecasts and data.* Retrieved from http://www.wtrg.com/

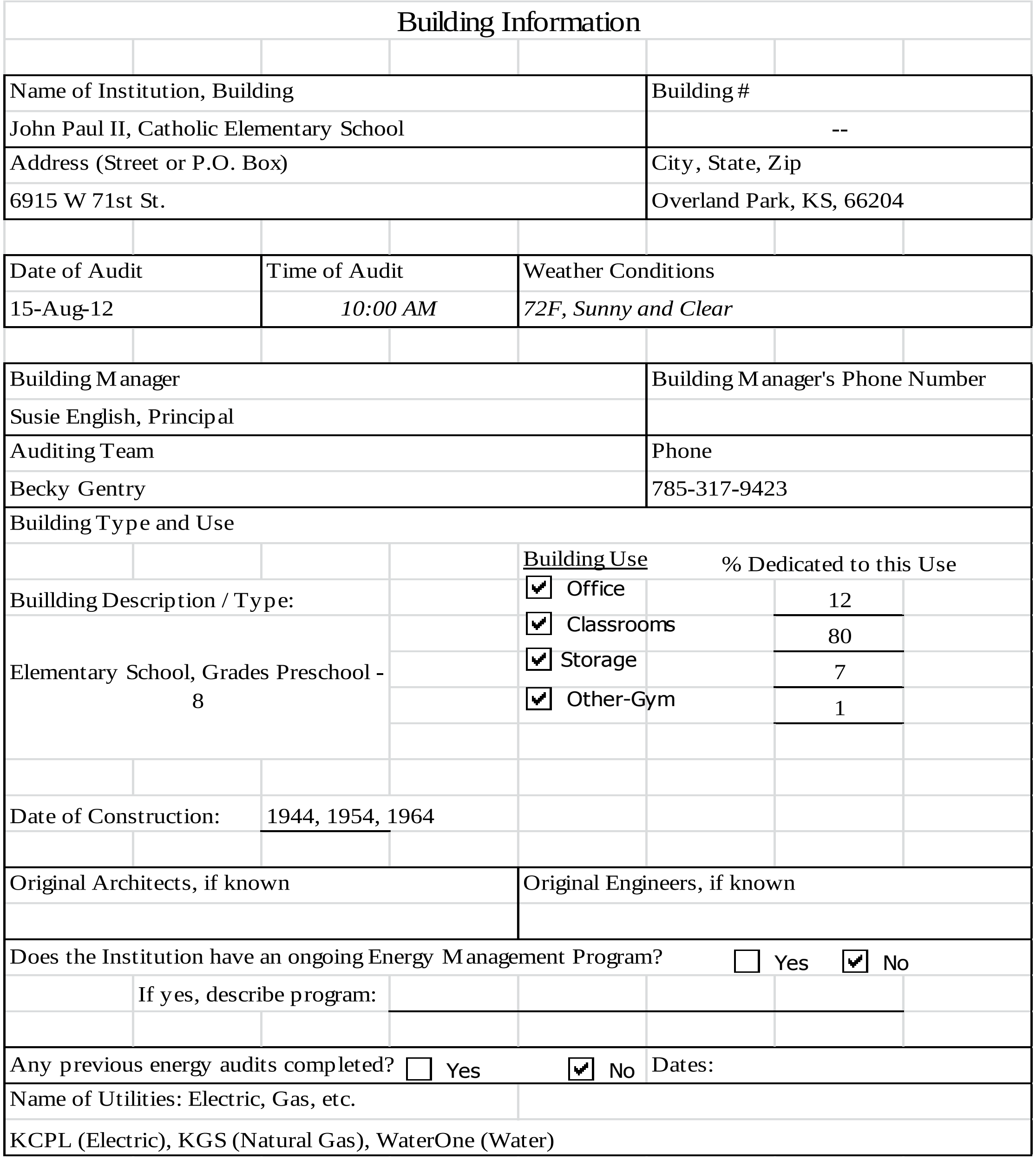
Yu, Z., Fung, B. C., Haghighat, F., Yoshino, H., & Morofsky, E. (2011). A systematic procedure to study the influence of occupant behavior on building energy consumption. Elsevier. 1-9.

Yun, G. Y., Kim, H., & Kim, J. T. (2011). Effects of occupancy and lighting use patterns on lighting energy consumption. Elsevier. 1-7.

Appendix A - Example Audit of Educational Facility

Within this appendix, the energy audit data, audit photographs, and the audit checklist are provided for the energy building audit performed at John Paul II Catholic Elementary School in Overland Park, Kansas.

Building Audit Data Worksheets



Building Information

Name of Institution, Building	Building #
John Paul II, Catholic Elementary School	--
Address (Street or P.O. Box)	City, State, Zip
6915 W 71st St.	Overland Park, KS, 66204

Date of Audit	Time of Audit	Weather Conditions
15-Aug-12	*10:00 AM*	*72F, Sunny and Clear*

Building Manager	Building Manager's Phone Number
Susie English, Principal	
Auditing Team	Phone
Becky Gentry	785-317-9423

Building Type and Use

Buillding Description / Type:

Elementary School, Grades Preschool - 8

Building Use	% Dedicated to this Use
☑ Office	12
☑ Classrooms	80
☑ Storage	7
☑ Other-Gym	1

Date of Construction: 1944, 1954, 1964

Original Architects, if known	Original Engineers, if known

Does the Institution have an ongoing Energy Management Program? ☐ Yes ☑ No

If yes, describe program:

Any previous energy audits completed? ☐ Yes ☑ No Dates:

Name of Utilities: Electric, Gas, etc.

KCPL (Electric), KGS (Natural Gas), WaterOne (Water)

Building Information

List of Energy Savings Programs or Efforts Currently Implemented:

1. Replaced some windows from single pane to double pane, 2 years ago

2. Plan to continue window renovations when finances are available

3.______________________________ ___________

4.______________________________ ___________

5.______________________________ ___________

Conservation Measures Under Consideration Prior to this Audit.

1. Replacing more of the single-pane windows with double-pane

2.______________________________

3.______________________________

4.______________________________

What are the facility manager's feelings towards saving energy?

Priority of Saving Energy and Money with Utilities? 1 2 3 4 5 6 7 8 [✓ 9 10]

What are the barriers to implementing energy saving strategies?

☑ Lack of Information

☑ Lack of Funds

☐ Lack of Support from Upper Management

☐ Other : ______________________

Building Information

Building Occupancy Profile

Typical Occupied Periods:

	Hours (i.e. 8am - 5pm)
Sunday	9am-12pm (Religion Classes)
Monday	7am-6pm
Tuesday	7am-6pm
Wednesday	7am-6pm
Thursday	7am-6pm
Friday	7am-6pm
Saturday	9am-5pm (on/off for sports)

Thermostat Set points:	Daytime	Heating	Controlled by boilers	Cooling	Individual window units in each room
	Nighttime	Heating		Cooling	
	Weekend	Heating		Cooling	

Average Number of Occupants in Building: 250

* all spaces were heated with radiators and cooled with window units.

<u>Include a Floor Plan.</u>

1. Look for discrepancies between plan and existing conditions.
2. Mark locations of heating and cooling units.

Definitions:

General

Good: In regards to an item being satisfactory in quality, quantity, or degree

Fair: In regards to an item being neither good nor poor; moderate or tolerable

Poor: In regards to an item being deficient or lacking in something specified

Doors

Good: Door has no obvious defects (dents, scratches, cracks) and no visible gaps when shut

Fair: Door has minor defects (dents, scratches, cracks) that do not affect operation or allows gaps

Poor: Door has major defects (dents, scratches, cracks) that prevent proper operation and results in gaps to outside.

Windows

Good: Window has no obvious defects (scratches, cracks), no visible gaps when shut, glazing is intact

Fair: Window has minor defects (scratches, cracks) that do not affect operation or allow gaps, minor cracks in glazing

Poor: Window has major defects (scratches, cracks) that prevent proper operation and results in gaps to outside, extensive cracks in glazing

ROOM NAME: Mrs.Yankovich

ROOM NUMBER 200

Thermostat? ☐ Yes ☑ No Setting: ______ ° F

Temperature 81.1 ° F * 2 Radiators and A/C Window

Relative Humidity 47.6 %

Lighting:	Ballast	Footcandles	Controls
(30) T12 34W Fluorescent Lamps (15 Fixtures)	Magnetic	57.9	Toggle

All Lights On: Yes

Equipment:

		Quantity		
Exhaust Fan	☐ Yes ☑ No		Smartboard	1
Computer	☑ Yes ☐ No	1		
Ceiling Fan		2		
Projector		1		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ______ Door Condition:
Type: ______ ☐ Good
Size: ______ ☐ Fair
☐ Poor

Shop Doors: Quantity: ______ Door Condition:
Type: ______ ☐ Good
Size: ______ ☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 7, North Window Condition:
Type: Single Pane ☐ Good
Size: 3' x 3' ☑ Fair
☐ Poor

Windows: Quantity: ______ Window Condition:
Type: ______ ☐ Good
Size: ______ ☐ Fair
☐ Poor

ROOM NAME: Mrs. Janner

ROOM NUMBER 201

Thermostat? ☐ Yes ☑ No Setting: ____ ° F

Temperature 80.6 ° F

Relative Humidity 46.3 %

* 2 Radiators
and A/C Window Unit

Lighting:	Ballast	Footcandles	Controls
(30) T12 34W Fluorescent Lamps (15 Fixtures)	Magnetic	61.9	Toggle

All Lights On: Yes

Equipment:

		Quantity		
Exhaust Fan	☐ Yes ☐ No		Smartboard	1
Computer	☑ Yes ☐ No	1	Printer	1
Ceiling Fan		2		
Projector		1		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ____
Type: ____
Size: ____

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity: ____
Type: ____
Size: ____

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 7, North
Type: Single Pane
Size: 3' x 3'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows: Quantity: ____
Type: ____
Size: ____

Window Condition:
☐ Good
☐ Fair
☐ Poor

ROOM NAME: Mrs. Kolarik

ROOM NUMBER: 202

Thermostat? ☐ Yes ☑ No Setting: ° F

Temperature 79.1 ° F

Relative Humidity 45.5 %

* 2 Radiators
and A/C Window Unit

Lighting:	Ballast	Footcandles	Controls
(30) T12 34W Fluorescent Lamps (15 Fixtures)	Magnetic	33	Toggle

All Lights On: Yes

Equipment:

		Quantity		
Exhaust Fan	☐ Yes ☑ No		Smartboard	1
Computer	☑ Yes ☐ No	1	Printer	1
Ceiling Fan		2		
Projector		1		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 7, South
Type: Single Pane
Size: 3' x 3'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows: Quantity:
Type:
Size:

Window Condition:
☐ Good
☐ Fair
☐ Poor

ROOM NAME: Ms. Tepper

ROOM NUMBER: 203

Thermostat? ☐ Yes ☑ No Setting: ______ ° F

Temperature 78.4 ° F

* 2 Radiators and A/C Window Unit

Relative Humidity 50.5 %

Lighting:	Ballast	Footcandles	Controls
(30) T12 34W Fluorescent Lamps (15 Fixtures)	Magnetic	45.1	Toggle

All Lights On: Yes

Equipment:

		Quantity		
Exhaust Fan	☐ Yes ☑ No		Smartboard	1
Computer	☑ Yes ☐ No	1	Printer	1
Ceiling Fan		2		
Projector		1		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ______
Type: ______
Size: ______

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity: ______
Type: ______
Size: ______

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 7
Type: South, Single Pane, No Glazing
Size: 3' x 3'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows: Quantity: ______
Type: ______
Size: ______

Window Condition:
☐ Good
☐ Fair
☐ Poor

ROOM NAME: Wuller's Wing - 2nd Floor Hall

ROOM NUMBER: ____

Thermostat? ☐ Yes ☑ No Setting: ____ ° F

Temperature 78.6 ° F * 2 Radiators

Relative Humidity 63.5 %

Lighting:	Ballast	Footcandles	Controls
(12) T12 34W Fluorescent Lamps (6 Fixtures)	Magnetic	6.6	Toggle

All Lights On: Yes

Equipment:

		Quantity
Exhaust Fan	☐ Yes ☑ No	
Computer	☐ Yes ☑ No	
Water Fountains		3

Exterior Doors: ☑ Yes ☐ No

Standard Doors: Quantity: 1

Type: East, Wood W/ Glass Panel

Size: 3' x 7'

Door Condition: ☐ Good ☑ Fair ☐ Poor

Shop Doors: Quantity: ____

Type: ____

Size: ____

Door Condition: ☐ Good ☐ Fair ☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 60

Type: East, Glass Blocks

Size: 6" x 6"

Window Condition: ☐ Good ☑ Fair ☐ Poor

Windows: Quantity: 2

Type: West, Single Pane

Size: 3' x 5'

Window Condition: ☐ Good ☐ Fair ☑ Poor

ROOM NAME: Girls Bath Off Wuller Wing, Plus Janitor Closet

ROOM NUMBER: ______

Thermostat? ☐ Yes ☑ No Setting: ______ ° F

Temperature 78 ° F * 1 Radiator
Relative Humidity 56.6 %

Lighting:	Ballast	Footcandles	Controls
(4) T12 34W Fluorescent Lamps	Magnetic	55.9	Toggle
(1) 60W Incandescent Lamp			

All Lights On: Yes

Equipment:

		Quantity		
Exhaust Fan	☐ Yes ☑ No		Janitor Sink	1
Computer	☐ Yes ☑ No			
FV Water Closets		7	* Water: Hi > 110F	
Lavatories		2		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ______
Type: ______
Size: ______

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity: ______
Type: ______
Size: ______

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 96
Type: South, Glass Blocks
Size: 6" x 6"

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows: Quantity: 1
Type: West, Single Pane
Size: 3' x 6'

Window Condition:
☐ Good
☑ Fair
☐ Poor

ROOM NAME: Staff Restroom

ROOM NUMBER:

Thermostat? ☐ Yes ☑ No Setting: ° F

Temperature 77.1 ° F * 1 Radiator

Relative Humidity 59.3 %

Lighting:	Ballast	Footcandles	Controls
(4) 60W Incandescent Lamps		32.2	Toggle

All Lights On: No

Equipment:

		Quantity
Exhaust Fan	☐ Yes ☑ No	
Computer	☐ Yes ☑ No	
FV Water Closets		1
Lavatories		1

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 1
Type: South, Single Pane
Size: 3' x 4'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows: Quantity:
Type:
Size:

Window Condition:
☐ Good
☐ Fair
☐ Poor

ROOM NAME: Transition Hallway w/ Stairs and Vestibule

ROOM NUMBER: ________

Thermostat? ☐ Yes ☑ No Setting: ________ ° F

Temperature 78.6 ° F * 1 Radiator

Relative Humidity 63.5 %

Lighting:	Ballast	Footcandles	Controls
(8) T12 34W Fluorescent Lamps (4 fixtures)	Magnetic	48.4	Toggle

All Lights On: Yes

Equipment:

			Quantity
Exhaust Fan	☐ Yes	☑ No	
Computer	☐ Yes	☑ No	

Exterior Doors: ☑ Yes ☐ No

Standard Doors: Quantity: 2, North

Type: Wood Doors w/ 70% Glass

Size: 3' x 7'

Door Condition: ☑ Good ☐ Fair ☐ Poor

Shop Doors: Quantity: ________

Type: ________

Size: ________

Door Condition: ☐ Good ☐ Fair ☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 48

Type: North, Glass Blocks

Size: 6" x 6"

Window Condition: ☐ Good ☑ Fair ☐ Poor

Windows: Quantity: ________

Type: ________

Size: ________

Window Condition: ☐ Good ☐ Fair ☐ Poor

ROOM NAME: Mrs. Cushing

ROOM NUMBER: 207

Thermostat? ☐ Yes ☑ No Setting: ° F

Temperature 79.5 ° F * 4 Radiators and A/C Window Unit

Relative Humidity 51.6 %

Lighting:	Ballast	Footcandles	Controls
(12) T12 34W Fluorescent Lamps (6 Fixtures)	Magnetic	16.4	Toggle

All Lights On: Yes

Equipment:

			Quantity
Exhaust Fan	☐ Yes	☑ No	
Computer	☑ Yes	☐ No	1
Printer			1
Overhead			1

Ceiling Fans 2

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 4
Type: North, Double Pane
Size: 3' x 4'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows: Quantity: 5
Type: North, Double Pane
Size: 3' x 6'

Window Condition:
☐ Good
☑ Fair
☐ Poor

ROOM NAME: Mrs. Gorman

ROOM NUMBER: 206

Thermostat? ☐ Yes ☑ No Setting: ° F

Temperature 79.1 ° F * 4 Radiators and A/C Window Uni
Relative Humidity 50 %

Lighting:	Ballast	Footcandles	Controls
(12) T12 34W Fluorescent Lamps (6 fixtures)	Magnetic	35	Toggle

All Lights On: Yes

Equipment:

		Quantity		
Exhaust Fan	☐ Yes ☑ No		Ceiling Fans	2
Computer	☑ Yes ☐ No	1	Projector	1
Printer		1	Smartboard	1
Overhead		1		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 5
Type: North, Double Pane
Size: 3' x 4'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows: Quantity: 6
Type: North, Double Pane
Size: 3' x 6'

Window Condition:
☐ Good
☑ Fair
☐ Poor

ROOM NAME: Class near Mrs. Gorman

ROOM NUMBER: n/a

Thermostat? ☐ Yes ☑ No Setting: ____ ° F

Temperature 79.1 ° F * 4 Radiators and A/C Window Uni

Relative Humidity 50 %

Lighting:	Ballast	Footcandles	Controls
(12) T12 34W Fluorescent Lamps (6 fixtures)	Magnetic	35	Toggle

All Lights On: Yes

Equipment:

			Quantity		
Exhaust Fan	☐ Yes	☑ No		Ceiling Fans	2
Computer	☑ Yes	☐ No	1	Projector	1
Printer			1	Smartboard	1
Overhead			1		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ____ Door Condition:
Type: ____ ☐ Good
Size: ____ ☐ Fair
☐ Poor

Shop Doors: Quantity: ____ Door Condition:
Type: ____ ☐ Good
Size: ____ ☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 5 Window Condition:
Type: South, Double Pane ☐ Good
Size: 3' x 4' ☑ Fair
☐ Poor

Windows: Quantity: 6 Window Condition:
Type: South, Double Pane ☐ Good
Size: 3' x 6' ☑ Fair
☐ Poor

ROOM NAME: Gym, plus teacher office

ROOM NUMBER: Gym

Thermostat? ☑ Yes ☐ No Setting: 75 ° F

Temperature 80.1 ° F *old thermostat, no programming avail.

Relative Humidity 62 % * 1 Radiator in Hall area

Lighting:	Ballast	Footcandles	Controls
(8) Metal Halides		--	Toggle
Daylight		74.1	

All Lights On: No

Equipment:

			Quantity		
Exhaust Fan	☐ Yes	☑ No		Pop Machine	1
Computer	☑ Yes	☐ No	1	TV	1
Fans			6		
Exhaust/Attic Fans			3		

Exterior Doors: ☑ Yes ☐ No

Standard Doors:
Quantity: 2
Type: East, Glass Doors
Size: 3' x 7'

Door Condition:
☑ Good
☐ Fair
☐ Poor

Shop Doors:
Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows:
Quantity: (10) East, (10) West
Type: Single Pane
Size: 3'x4'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows:
Quantity: (3) North, (6) South
Type: Single Pane
Size: 2'x7'

Window Condition:
☐ Good
☑ Fair
☐ Poor

ROOM NAME: Office / Principal's Office

ROOM NUMBER: 100

Thermostat? ☐ Yes ☑ No Setting: ° F

Temperature 80.9 ° F

Relative Humidity 55.2 %

Lighting:	Ballast	Footcandles	Controls
(36) T12 34W Fluorescent Lamps (18 fixtures)	Magnetic	95.6	Toggle

All Lights On: Yes

Equipment:

		Quantity
Exhaust Fan	☐ Yes ☑ No	
Computer	☑ Yes ☐ No	4
Combo Printer		1
Personal Printer		2

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 8, East
Type: Single Pane
Size: 3'x8'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows: Quantity:
Type:
Size:

Window Condition:
☐ Good
☐ Fair
☐ Poor

ROOM NAME: Room 105

ROOM NUMBER: 105

Thermostat? ☐ Yes ☐ No Setting: ____ ° F

Temperature 80.9 ° F

* 2 Radiators, 1 Window Unit

Relative Humidity 47.5 %

Lighting:	Ballast	Footcandles	Controls
(30) T12 34W Fluorescent Lamps (15 fixtures)	Magnetic	34.9	Toggle

All Lights On: Yes

Equipment:

		Quantity
Exhaust Fan	☐ Yes ☐ No	
Computer	☑ Yes ☐ No	2
Printer		1

Exterior Doors: ☐ Yes ☑ No

Standard Doors:
Quantity: ____
Type: ____
Size: ____

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors:
Quantity: ____
Type: ____
Size: ____

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows:
Quantity: 6, West
Type: Single Pane
Size: 3'x8'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows:
Quantity: ____
Type: ____
Size: ____

Window Condition:
☐ Good
☐ Fair
☐ Poor

ROOM NAME: Office Closet Area

ROOM NUMBER:

Thermostat? ☐ Yes ☑ No Setting: ° F

Temperature 80.6 ° F

Relative Humidity 50 %

Lighting:	Ballast	Footcandles	Controls
(4) T12 34W Fluorescent Lamps (2 fixtures)	Magnetic	56.3	Toggle

All Lights On: No

Equipment:

		Quantity
Exhaust Fan	☐ Yes ☑ No	
Computer	☐ Yes ☑ No	
Big Copier		1

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity:
Type:
Size:
Door Condition: ☐ Good ☐ Fair ☐ Poor

Shop Doors: Quantity:
Type:
Size:
Door Condition: ☐ Good ☐ Fair ☐ Poor

Exterior Windows: ☐ Yes ☑ No

Windows: Quantity:
Type:
Size:
Window Condition: ☐ Good ☐ Fair ☐ Poor

Windows: Quantity:
Type:
Size:
Window Condition: ☐ Good ☐ Fair ☐ Poor

ROOM NAME: Teacher Lounge
ROOM NUMBER: 103

Thermostat? ☐ Yes ☑ No Setting: ° F

Temperature 80 ° F

* 2 Radiators, 1 Window Unit

Relative Humidity 56.3 %

Lighting:	Ballast	Footcandles	Controls
(8) T12 34W Fluorescent Lamps (4 fixtures)	Magnetic	31.8	Toggle

All Lights On: No

Equipment:

		Quantity		
Exhaust Fan	☐ Yes ☑ No		Microwave	1
Computer	☐ Yes ☑ No		Coffee Maker	1
Pop Machine		1	Printer	1
Fridge		1		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 4, South
Type: Single Pane
Size: 3'x8'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows: Quantity:
Type:
Size:

Window Condition:
☐ Good
☐ Fair
☐ Poor

ROOM NAME: First Floor Main Hallway

ROOM NUMBER: ____

Thermostat? ☐ Yes ☑ No Setting: ____ ° F

Temperature 79.8 ° F * 6 Radiators

Relative Humidity 52.1 %

Lighting:	Ballast	Footcandles	Controls
(8) T12 34W Fluorescent Lamps (4 fixtures)	Magnetic	31.8	Toggle

All Lights On: Yes

Equipment:

		Quantity
Exhaust Fan	☐ Yes ☑ No	
Computer	☐ Yes ☑ No	
Janitor Sink		1
Water Fountains		5

Exterior Doors: ☑ Yes ☐ No

Standard Doors: Quantity: 4, North
Type: Metal, 80% Glass
Size: 3'x7'
Door Condition: ☑ Good ☑ Fair ☐ Poor

Standard Doors: Quantity: 2, East
Type: Metal, 50% Glass
Size: 3'x7'
Door Condition: ☐ Good ☑ Fair ☐ Poor

Exterior Windows: ☐ Yes ☑ No

Windows: Quantity: ____
Type: ____
Size: ____
Window Condition: ☐ Good ☐ Fair ☐ Poor

Windows: Quantity: ____
Type: ____
Size: ____
Window Condition: ☐ Good ☐ Fair ☐ Poor

ROOM NAME: Men's Restrooms (2 in 1st Floor Hall)

ROOM NUMBER:

Thermostat? ☐ Yes ☑ No Setting: ° F

Temperature -- ° F * 1 Radiator

Relative Humidity -- %

Lighting:	Ballast	Footcandles	Controls
(1) 60W Incandescent Lamp			
(6) T12 34W Fluorescent Lamps (3 fixtures)	Magnetic	21.2	Toggle

All Lights On: Yes

Equipment:		Quantity		
Exhaust Fan	☐ Yes ☑ No		FV Water Closet	4
Computer	☐ Yes ☑ No		FV Urinals	4
Janitor Sink		1		
Lavatories		3		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 1, West
Type: Single Pane
Size: 3'x6'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows: Quantity:
Type:
Size:

Window Condition:
☐ Good
☐ Fair
☐ Poor

ROOM NAME: Women's Restrooms (2 in 1st Floor Hall)

ROOM NUMBER:

Thermostat? ☐ Yes ☑ No Setting: ° F

Temperature -- ° F * 1 Radiator
Relative Humidity -- %

Lighting:	Ballast	Footcandles	Controls
(1) 60W Incandescent Lamp			
(6) T12 34W Fluorescent Lamps (3 fixtures)	Magnetic	23.4	Toggle

All Lights On: Yes

Equipment:

		Quantity
Exhaust Fan	☐ Yes ☑ No	
Computer	☐ Yes ☑ No	
Lavatories		3
FV Water Closets		9

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity:
Type:
Size:
Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity:
Type:
Size:
Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☐ Yes ☐ No

Windows: Quantity: 1, West
Type: Single Pane
Size: 3'x6'
Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows: Quantity: 1, East
Type: Single Pane
Size: 3'x3'
Window Condition:
☐ Good
☑ Fair
☐ Poor

ROOM NAME: Music

ROOM NUMBER 102

Thermostat? ☐ Yes ☑ No Setting: ____ ° F

Temperature 80.2 ° F * 2 Radiators, 2 Window Units
Relative Humidity 75.4 %

Lighting:	Ballast	Footcandles	Controls
(30) T12 34W Fluorescent Lamps (15 fixtures)	Magnetic	52	Toggle

All Lights On: Yes

Equipment:

		Quantity		
Exhaust Fan	☐ Yes ☑ No		Elec Keyboarc	1
Computer	☑ Yes ☐ No	1	Ceiling Fans	2
TV		1		
Printer		1		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ____ Door Condition:
Type: ____ ☐ Good
Size: ____ ☐ Fair
☐ Poor

Shop Doors: Quantity: ____ Door Condition:
Type: ____ ☐ Good
Size: ____ ☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 6, East Window Condition:
Type: Single Pane ☐ Good
Size: 3'x8' ☑ Fair
☐ Poor

Windows: Quantity: ____ Window Condition:
Type: ____ ☐ Good
Size: ____ ☐ Fair
☐ Poor

ROOM NAME: Kindergarten

ROOM NUMBER: 104

Thermostat? ☐ Yes ☑ No Setting: ____ ° F

Temperature 80.4 ° F

* 2 Radiators, 1 Window Units

Relative Humidity 45.5 %

Lighting:	Ballast	Footcandles	Controls
(30) T12 34W Fluorescent Lamps (15 fixtures)	Magnetic	35.9	Toggle

All Lights On: Yes

Equipment:

			Quantity		
Exhaust Fan	☐ Yes	☑ No		Smartboard	1
Computer	☑ Yes	☐ No	2		
Printer			1		
Projector			1		

Exterior Doors: ☐ Yes ☑ No

Standard Doors:
Quantity: ____
Type: ____
Size: ____

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors:
Quantity: ____
Type: ____
Size: ____

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows:
Quantity: 6, West
Type: Single Pane
Size: 3'x8'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows:
Quantity: ____
Type: ____
Size: ____

Window Condition:
☐ Good
☐ Fair
☐ Poor

ROOM NAME: Kitchen

ROOM NUMBER:

Thermostat? ☑ Yes ☐ No Setting: n/a ° F

(Wasn't On)

Temperature 79.5 ° F

* 1 Window Unit

Relative Humidity 67.5 %

Lighting:	Ballast	Footcandles	Controls
(14) T12 34W Fluorescent Lamps (7 fixtures)	Magnetic	75.7	Toggle

All Lights On: Yes

Equipment:

			Quantity		
			Quantity	Dishwasher w/ Booster Heater	1
Exhaust Fan	☑ Yes	☐ No	1	Oven	3
Computer	☐ Yes	☑ No		Pan Warmer	1
Ceiling Fans			2	Fridge	5
Carafe Warmer			1	Kitchen Sinks	3
Gas 10-Burner Stove w/ Hood			1	Mixer	1

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 4, South
Type: Single Pane
Size: 2'x4'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows: Quantity: 5, South
Type: Single Pane
Size: 4'x5'

Window Condition:
☐ Good
☑ Fair
☐ Poor

ROOM NAME: Cafeteria

ROOM NUMBER: ______

Thermostat? ☐ Yes ☑ No Setting: ______ ° F

Temperature 80 ° F * 6 Radiators, 2 Window Units

Relative Humidity 56.4 %

Lighting:	Ballast	Footcandles	Controls
(74) T12 34W Fluorescent Lamps (37 fixtures)	Magnetic	88.7	Toggle

All Lights On: Yes

Equipment:

		Quantity
Exhaust Fan	☐ Yes ☑ No	
Computer	☐ Yes ☑ No	
Ceiling Fans		8
Water Fountains		2

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ______ Door Condition:

Type: ______ ☐ Good

Size: ______ ☐ Fair

☐ Poor

Shop Doors: Quantity: ______ Door Condition:

Type: ______ ☐ Good

Size: ______ ☐ Fair

☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 10, South Window Condition:

Type: Single Pane ☐ Good

Size: 2'x4' ☑ Fair

☐ Poor

Windows: Quantity: 12, South Window Condition:

Type: Single Pane ☐ Good

Size: 4'x5' ☑ Fair

☐ Poor

ROOM NAME: Library

ROOM NUMBER: 111

Thermostat? ☐ Yes ☑ No Setting: ° F

Temperature 80 ° F

* 6 Radiators, 2 Window Units

Relative Humidity 62.7 %

Lighting:	Ballast	Footcandles	Controls
(50) T12 34W Fluorescent Lamps (25 fixtures)	Magnetic	32.7	Toggle

All Lights On: Yes

Equipment:

		Quantity		
Exhaust Fan	☐ Yes ☑ No		Smartboard	1
Computer	☑ Yes ☐ No	1	TV	1
Ceiling Fans		4		
Projector		1		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 10, North
Type: Single Pane
Size: 2.5' x 3'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows: Quantity:
Type:
Size:

Window Condition:
☐ Good
☐ Fair
☐ Poor

ROOM NAME: Maintenance Closet

ROOM NUMBER: ____

Thermostat? ☐ Yes ☑ No Setting: ____ ° F

Temperature -- ° F

Relative Humidity -- %

Lighting:	Ballast	Footcandles	Controls
(2) T12 34W Fluorescent Lamps (1 fixture)	Magnetic	--	Toggle

All Lights On: No

Equipment:

		Quantity
Exhaust Fan	☐ Yes ☑ No	
Computer	☐ Yes ☑ No	
Ceiling Fan		1

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ____

Type: ____

Size: ____

Door Condition:

☐ Good

☐ Fair

☐ Poor

Shop Doors: Quantity: ____

Type: ____

Size: ____

Door Condition:

☐ Good

☐ Fair

☐ Poor

Exterior Windows: ☐ Yes ☑ No

Windows: Quantity: ____

Type: ____

Size: ____

Window Condition:

☐ Good

☐ Fair

☐ Poor

Windows: Quantity: ____

Type: ____

Size: ____

Window Condition:

☐ Good

☐ Fair

☐ Poor

ROOM NAME: Nurses Office

ROOM NUMBER: 107

Thermostat? ☐ Yes ☑ No Setting: ____ ° F

Temperature 78.9 ° F * 1 Radiator, 1 Window Unit

Relative Humidity 54.1 %

Lighting:	Ballast	Footcandles	Controls
(2) T12 34W Fluorescent Lamp	Magnetic	67.3	Toggle
(1) 25W CFL			
(3) 60W Incandescent Lamps			

All Lights On: Yes

Equipment:

		Quantity		
Exhaust Fan	☐ Yes ☑ No		Mini-Fridge	1
Computer	☑ Yes ☐ No	1	FV Water C	1
Printer		1		
Lavatory		1		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ____ Door Condition:
Type: ____ ☐ Good
Size: ____ ☐ Fair
☐ Poor

Shop Doors: Quantity: ____ Door Condition:
Type: ____ ☐ Good
Size: ____ ☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 2, South Window Condition:
Type: Single Pane ☐ Good
Size: 2'x3' ☑ Fair
☐ Poor

Windows: Quantity: 3, South Window Condition:
Type: Single Pane ☐ Good
Size: 3'x6' ☐ Fair
☐ Poor

ROOM NAME: Mrs. McGill

ROOM NUMBER: 106 * Room Locked

Thermostat? ☐ Yes ☑ No Setting: ______ ° F

Temperature ______ ° F * 2 Radiators, 1 Window Unit
Relative Humidity ______ %

Lighting:	Ballast	Footcandles	Controls
(8) T12 34W Fluorescent Lamps (4 fixtures)	Magnetic	--	Toggle

All Lights On: No

Equipment:

		Quantity
Exhaust Fan	☐ Yes ☑ No	
Computer	☑ Yes ☐ No	1
Ceiling Fan		1

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ______
Type: ______
Size: ______

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity: ______
Type: ______
Size: ______

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 2, South
Type: Single Pane
Size: 2.5' x 3'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows: Quantity: ______
Type: ______
Size: ______

Window Condition:
☐ Good
☐ Fair
☐ Poor

ROOM NAME: Office Area (Near Kitchen)

ROOM NUMBER: ______

Thermostat? ☑ Yes ☐ No Setting: 72 ° F

* Connected to Fan Coil Unit in Roor

Temperature 79.3 ° F

Relative Humidity 56.1 %

* 2 Radiators

Lighting:	Ballast	Footcandles	Controls
(24) T12 34W Fluorescent Lamps (12 fixtures)	Magnetic	24.1	Toggle

All Lights On: Yes

Equipment:

		Quantity		
Exhaust Fan	☐ Yes ☑ No		TV	1
Computer	☑ Yes ☐ No	3	Ceiling Fan	2
Freezers		2	Microwave	1
Printers		2	Mini-Fridge	1

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ______

Type: ______

Size: ______

Door Condition:

☐ Good

☐ Fair

☐ Poor

Shop Doors: Quantity: ______

Type: ______

Size: ______

Door Condition:

☐ Good

☐ Fair

☐ Poor

Exterior Windows: ☐ Yes ☑ No

Windows: Quantity: ______

Type: ______

Size: ______

Window Condition:

☐ Good

☐ Fair

☐ Poor

Windows: Quantity: ______

Type: ______

Size: ______

Window Condition:

☐ Good

☐ Fair

☐ Poor

ROOM NAME: Work Room

ROOM NUMBER: ____

Thermostat? ☐ Yes ☑ No Setting: ____ ° F

Temperature 78.9 ° F

Relative Humidity 61.3 %

Lighting:	Ballast	Footcandles	Controls
(24) T12 34W Fluorescent Lamps (12 fixtures)	Magnetic	93.5	Toggle

All Lights On: Yes

Equipment:

		Quantity		
Exhaust Fan	☑ Yes ☐ No	1	Fans	2
Computer	☐ Yes ☑ No			
Laminator		1		
Big Combo Printer		1		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ____ Type: ____ Size: ____

Door Condition: ☐ Good ☐ Fair ☐ Poor

Shop Doors: Quantity: ____ Type: ____ Size: ____

Door Condition: ☐ Good ☐ Fair ☐ Poor

Exterior Windows: ☐ Yes ☑ No

Windows: Quantity: ____ Type: ____ Size: ____

Window Condition: ☐ Good ☐ Fair ☐ Poor

Windows: Quantity: ____ Type: ____ Size: ____

Window Condition: ☐ Good ☐ Fair ☐ Poor

ROOM NAME: Mrs. Hogue/Daycare

ROOM NUMBER: 205

Thermostat? ☐ Yes ☑ No Setting: ____ ° F

Temperature 81.1 ° F * 8 Radiators, 2 Window Units

Relative Humidity 54.2 %

Lighting:	Ballast	Footcandles	Controls
(12) T12 34W Fluorescent Lamps	Magnetic	28.2	Toggle
(16) T12 34W Fluorescent Lamps	Magnetic	36.1	Toggle

All Lights On: Yes

Equipment:

		Quantity
Exhaust Fan	☐ Yes ☑ No	
Computer	☐ Yes ☑ No	
Ceiling Fans		4
TV		1

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ____ Door Condition:

Type: ____ ☐ Good

Size: ____ ☐ Fair

☐ Poor

Shop Doors: Quantity: ____ Door Condition:

Type: ____ ☐ Good

Size: ____ ☐ Fair

☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 12, South Window Condition:

Type: Single Pane ☐ Good

Size: 2'x3' ☑ Fair

☐ Poor

Windows: Quantity: 14, South Window Condition:

Type: Single Pane ☐ Good

Size: 3'x6' ☑ Fair

☐ Poor

ROOM NAME: Mr. Owsley

ROOM NUMBER: 101 * ROOM LOCKED

Thermostat? ☐ Yes ☑ No Setting: ______ ° F

Temperature -- ° F

Relative Humidity -- %

* 2 Radiators, 1 Window Unit

Lighting:	Ballast	Footcandles	Controls
(30) T12 34W Fluorescent Lamps (15 fixtures)	Magnetic	--	Toggle

All Lights On: No

Equipment:

		Quantity
Exhaust Fan	☐ Yes ☑ No	
Computer	☑ Yes ☐ No	1
Printer		1
Microwave		1

Ceiling Fans	2
Projector	1
Smartboard	1

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ______ Type: ______ Size: ______

Door Condition: ☐ Good ☐ Fair ☐ Poor

Shop Doors: Quantity: ______ Type: ______ Size: ______

Door Condition: ☐ Good ☐ Fair ☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 3, North

Type: Single Pane

Size: 3'x3'

Window Condition: ☐ Good ☑ Fair ☐ Poor

Windows: Quantity: ______ Type: ______ Size: ______

Window Condition: ☐ Good ☐ Fair ☐ Poor

ROOM NAME: Mrs. South

ROOM NUMBER: 102

Thermostat? ☐ Yes ☑ No Setting: ____ ° F

Temperature 78 ° F

Relative Humidity 60.2 %

* 2 Radiators, 1 Window Unit

Lighting:	Ballast	Footcandles	Controls
(30) T12 34W Fluorescent Lamps (15 fixtures)	Magnetic	20.8	Toggle

All Lights On: Yes

Equipment:

		Quantity		
Exhaust Fan	☐ Yes ☑ No		Projector	1
Computer	☑ Yes ☐ No	1	Smartboard	1
Printer		1		
Ceiling Fans		2		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ____ Type: ____ Size: ____

Door Condition: ☐ Good ☐ Fair ☐ Poor

Shop Doors: Quantity: ____ Type: ____ Size: ____

Door Condition: ☐ Good ☐ Fair ☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 7, South Type: Single Pane Size: 3'x3'

Window Condition: ☐ Good ☑ Fair ☐ Poor

Windows: Quantity: ____ Type: ____ Size: ____

Window Condition: ☐ Good ☐ Fair ☐ Poor

ROOM NAME: Mrs. Brown

ROOM NUMBER: 103

Thermostat? ☐ Yes ☑ No Setting: ____ ° F

Temperature 78.8 ° F

Relative Humidity 57 %

* 2 Radiators, 1 Window Unit

Lighting:	Ballast	Footcandles	Controls
(30) T12 34W Fluorescent Lamps (15 fixtures)	Magnetic	36.4	Toggle

All Lights On: Yes

Equipment:

		Quantity		
Exhaust Fan	☐ Yes ☑ No		Projector	1
Computer	☑ Yes ☐ No	1	Smartboard	1
Printer		1	Service Sinks	2
Ceiling Fans		2		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ____
Type: ____
Size: ____

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity: ____
Type: ____
Size: ____

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 7, South
Type: Single Pane
Size: 3'x3'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows: Quantity: ____
Type: ____
Size: ____

Window Condition:
☐ Good
☐ Fair
☐ Poor

ROOM NAME: Mr. Yedo Computer

ROOM NUMBER: 100

Thermostat? ☐ Yes ☑ No Setting: ____ ° F

Temperature 78.8 ° F

Relative Humidity 56.1 %

* 2 Radiators, 1 Window Unit

Lighting:	Ballast	Footcandles	Controls
(30) T12 34W Fluorescent Lamps (15 fixtures)	Magnetic	36.3	Toggle

All Lights On: Yes

Equipment:

		Quantity		
Exhaust Fan	☐ Yes ☑ No		Projector	1
Computer	☑ Yes ☐ No	30	Smartboard	1
Printer		4		
Ceiling Fans		3		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ____

Type: ____

Size: ____

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity: ____

Type: ____

Size: ____

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 3, North

Type: Single Pane

Size: 3'x3'

Window Condition:
☐ Good
☑ Fair
☐ Poor

Windows: Quantity: ____

Type: ____

Size: ____

Window Condition:
☐ Good
☐ Fair
☐ Poor

ROOM NAME: Women's Restroom

ROOM NUMBER:

Thermostat? ☐ Yes ☑ No Setting: ° F

Temperature 78.8 ° F

Relative Humidity 57.2 %

* 2 Radiators

Lighting:	Ballast	Footcandles	Controls
(8) T12 34W Fluorescent Lamps (4 fixtures)	Magnetic	55.2	Toggle

All Lights On: No

Equipment:		Quantity
Exhaust Fan	☐ Yes ☑ No	
Computer	☐ Yes ☑ No	
Lavatories		2
FV Water Closets		2

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity:

Type:

Size:

Door Condition: ☐ Good ☐ Fair ☐ Poor

Shop Doors: Quantity:

Type:

Size:

Door Condition: ☐ Good ☐ Fair ☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 2, South

Type: Single Pane

Size: 2.5' x 3'

Window Condition: ☐ Good ☑ Fair ☐ Poor

Windows: Quantity:

Type:

Size:

Window Condition: ☐ Good ☐ Fair ☐ Poor

ROOM NAME: Men's Restroom (Near 103)

ROOM NUMBER: ______

Thermostat? ☐ Yes ☑ No Setting: ______ ° F

Temperature 78.6 ° F
Relative Humidity 55.9 %

Lighting:	Ballast	Footcandles	Controls
(4) T12 34W Fluorescent Lamps	Magnetic	14.6	Toggle
(1) 60W Incandescent Lamp			

All Lights On: No

Equipment:

		Quantity		
Exhaust Fan	☐ Yes ☑ No		Janitor Sink	1
Computer	☐ Yes ☑ No		Lavatories	2
FV Water Closets		4		
FV Urinals		4		

Exterior Doors: ☐ Yes ☑ No

Standard Doors: Quantity: ______
Type: ______
Size: ______
Door Condition: ☐ Good ☐ Fair ☐ Poor

Shop Doors: Quantity: ______
Type: ______
Size: ______
Door Condition: ☐ Good ☐ Fair ☐ Poor

Exterior Windows: ☑ Yes ☐ No

Windows: Quantity: 1, South
Type: Single Pane
Size: 3'x6'
Window Condition: ☐ Good ☐ Fair ☐ Poor

Windows: Quantity: ______
Type: ______
Size: ______
Window Condition: ☐ Good ☐ Fair ☐ Poor

ROOM NAME: Hallway under Wuller's Wing

ROOM NUMBER:

Thermostat? ☐ Yes ☑ No Setting: ____ ° F

Temperature 77.7 ° F

Relative Humidity 65.6 %

Lighting:	Ballast	Footcandles	Controls
(10) T12 34W Fluorescent Lamps	Magnetic	8.1	Toggle
(12) T12 34W Fluorescent Lamps	Magnetic	15.2	Toggle

All Lights On: No

Equipment:		Quantity
Exhaust Fan	☐ Yes ☑ No	
Computer	☐ Yes ☑ No	
Water Fountain		1

Exterior Doors: ☑ Yes ☐ No

Standard Doors:
Quantity: 1, East
Type: Wood, 50% Glass
Size: 3'x7'

Door Condition:
☑ Good
☐ Fair
☐ Poor

Shop Doors:
Quantity:
Type:
Size:

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☐ Yes ☑ No

Windows:
Quantity:
Type:
Size:

Window Condition:
☐ Good
☐ Fair
☐ Poor

Windows:
Quantity:
Type:
Size:

Window Condition:
☐ Good
☐ Fair
☐ Poor

Building Characteristics

Gross Floor Area		gross sf	,	ceiling ht		ft	
		gross sf	,	ceiling ht		ft	* If multiple ceiling
		gross sf	,	ceiling ht		ft	heights
Conditioned Floor Area	Heating Only:				sf		
	Cooling Only:				sf	Area information was not inputted due to lack in building floor plans	
	Heating and Cooling:				sf		
Number of Conditioned Floors:							
	Above Grade			1			
	Below Grade			1			
Total Standard Door	252	sf		Glass	159.6	sf	Door Condition:
				Wood	54.6	sf	☐ Good
				Metal	37.8	sf	☑ Fair
				Garage		sf	☐ Poor
Total Shop Door	0	sf		Glass		sf	Door Condition:
				Wood		sf	☐ Good
				Metal		sf	☐ Fair
				Garage		sf	☐ Poor
Exterior Glass Area	3068	sf		Single Panes	2594	sf	Window Condition:
(Note: Operable or Fixed)				Double Panes	474	sf	☐ Good
							☑ Fair
			North	Total Area	603	sf	☐ Poor
				Single Panes	297	sf	
				Double Panes	306	sf	
			South	Total Area	1508	sf	
				Single Panes	1340	sf	
				Double Panes	168	sf	
			East	Total Area	465	sf	
				Single Panes	465	sf	
				Double Panes	0	sf	
			West	Total Area	492	sf	
				Single Panes	492	sf	
				Double Panes	0	sf	

Building Exterior Wall Area ________ sf
☑ Masonry ☐ Stucco
☐ Wood ☐ Other
☐ Concrete ☐ Unknown
Just layer of brick, no insulation

Building Interior Walls ________ sf
☑ Masonry ☐ Stucco
☐ Wood ☐ Other
☐ Concrete ☐ Unknown
*CMU Walls

Total Roof Area ________ sf
Condition: ☐ Good
☐ Fair
☐ Poor

Insulation Type:
Roof: ________
Wall: ________
Floor: ________

Insulation Thickness:
Roof: ________
Wall: ________
Floor: ________

If Provided on Building Plans.

Metering:

Is this building individually metered for electricity?	☑ Yes	☐ No
Is this building individually metered for natural gas / LP?	☑ Yes	☐ No
Is this building individually metered for water?	☑ Yes	☐ No

Describe the general building condition:

Building is in generally good condition. There are some wall areas that need to be resealed. The walls are very thin construction and a temperature difference can be felt moving through different sections of the wall.

HEATING PLANT

PRIMARY

SYSTEM TYPE	Quantity	Rated Input	Rated Output
☐ Fire Tube-Steam			
☐ Water Tube-Steam			
☑ Fire Tube-Hot Water	2	1500000	1200000
☐ Water Tube-Hot Water			
☐ Electric Resistance			
☐ Heat Pump, Aux. Elec Heat			
☐ Purchased Steam			
☐ Other			

ENERGY SOURCE

- ☑ Natural Gas
- ☐ LP Gas
- ☐ #2 Fuel Oil
- ☐ #4 Fuel Oil
- ☐ #6 Fuel Oil
- ☐ Electricity
- ☐ Coal
- ☐ Wood
- ☐ Solar
- ☐ Puchased Steam

MAINTENANCE

- ☐ Good
- ☐ Fair
- ☑ Poor

CONTROLS

- ☑ Manual
- ☐ Somewhat Automated
- ☐ Highly Automated

Rite Boiler, Max Water Pressure: 125lb, Model 150, Serial 3747L10 and Smith Cast Iron Boiler

SECONDARY

SYSTEM TYPE	Quantity	Rated Input	Rated Output
☐ Fire Tube-Steam			
☐ Water Tube-Steam			
☐ Fire Tube-Hot Water			
☐ Water Tube-Hot Water			
☐ Electric Resistance			
☐ Heat Pump, Aux. Elec Heat			
☐ Purchased Steam			
☐ Other			

ENERGY SOURCE

- ☐ Natural Gas
- ☐ LP Gas
- ☐ #2 Fuel Oil
- ☐ #4 Fuel Oil
- ☐ #6 Fuel Oil
- ☐ Electricity
- ☐ Coal
- ☐ Wood
- ☐ Solar
- ☐ Puchased Steam

MAINTENANCE

- ☐ Good
- ☐ Fair
- ☐ Poor

CONTROLS

- ☐ Manual
- ☐ Somewhat Automated
- ☐ Highly Automated

Potential for Waste Heat Recovery?

☐ Yes ☐ No

SECONDARY #2

SYSTEM TYPE

	Quantity	Rated Input	Rated Output
☐ Fire Tube-Steam			
☐ Water Tube-Steam			
☐ Fire Tube-Hot Water			
☐ Water Tube-Hot Water			
☐ Electric Resistance			
☐ Heat Pump, Aux. Elec Heat			
☐ Purchased Steam			
☐ Other			

ENERGY SOURCE
- ☐ Natural Gas
- ☐ LP Gas
- ☐ #2 Fuel Oil
- ☐ #4 Fuel Oil
- ☐ #6 Fuel Oil
- ☐ Electricity
- ☐ Coal
- ☐ Wood
- ☐ Solar
- ☐ Puchased Steam

MAINTENANCE
- ☐ Good
- ☐ Fair
- ☐ Poor

CONTROLS
- ☐ Manual
- ☐ Somewhat Automated
- ☐ Highly Automated

Potential for Waste Heat Recovery?
☐ Yes ☐ No

OPERATION PROFILE

11 hrs/weekday

9 hrs/Saturday

4 hrs/Sunday

20 wks/yr

Estimated Annual Hours of Operatior 1360

From (month) October through March

Thermostat Set Points

Day: on at 150F/off

Night: on at 150F/off

Weekends on at 150F/off

(These are the boiler control points for heating up the hot water to be sent to the radiators)

HVAC DISTRIBUTION SYSTEM

Location of Unit(s)

Each room was heated with radiators and cooled with window units.

SYSTEM 1

SYSTEM TYPE

☐ Single Zone (Furnace, RTU, etc.)
☐ Multi Zone (i.e. AHU)
☐ Dual Duct
☐ Variable Air Volume
☐ Single Duct Reheat
☑ 2-Pipe Water - Perimeter Radiators
☐ 4-Pipe Water
☑ Window Unit
☐ Packaged Air Terminal Unit
☐ Unit Ventilator
☐ Fan Coil
☐ Unit Heater
☐ Other

MAINTENANCE

☐ Good
☑ Fair
☐ Poor

All radiators and window units were fairly maintained.

The radiators are supplied with hot water.

DUCTWORK

Insulation:
☐ Good
☐ Fair
☐ Poor

Installation:
☐ Good
☐ Fair
☐ Poor

CONTROLS

Style:

☐ Space Thermostat
☐ Outside Temperature Sensors
☐ Time Clocks
☐ Energy Management System
☐ Auto Supply Temperature Reset
☐ Economy Cycle
☐ Heat Recovery
☑ Other

The window units have integral controls and the radiators are controlled by the boiler that is on or off.

COOLING PLANT

PRIMARY

SYSTEM TYPE

☐ Reciprocating Chiller
☐ Centrifugal Chiller
☐ Absorption Chiller
☐ Solar Assisted-Absorption Chiller
☐ Evaporative Chiller
☐ Heat Pump
☐ DX System
☐ Screw Compressor
☑ Window or Thru-Wall Unit
☐ Other ________

ENERGY SOURCE

☑ Electric Motor
☐ Combustion Engine
☐ Steam Turbine
☐ Steam Boiler
☐ Purchased Steam
☐ Other ________

MAINTENANCE

☐ Good
☑ Fair
☐ Poor

CONTROLS

☑ Manual
☐ Somewhat Automated
☐ Highly Automated

VOLTAGE

☑ 120 / Single Phase
☐ 208-120 / Single Phase
☐ 208-220 / 3 Phase
☐ 440-480 / 3 Phase

OPERATION PROFILE

11 hrs/weekday
9 hrs/Saturday
4 hrs/Sunday
20 wks/yr

Estimated Annual Hours of Operation: 1360

From (month) August-Sept through April-May

Thermostat Set Points
Day: Integral Controls
Night: Integral Controls
Weekends: Integral Controls

DOMESTIC HOT WATER

Domestic Hot Water Heated By:

☐ Electricity
☑ Natural Gas
☐ Oil
☐ Steam
☐ Heat Pump
☐ Other

(2) 40 Gallon Water

Number of Units: 2
General Location of Units: Boiler Room
Is there a re-circulation loop? ☑ Yes ☐ No

Hot Water Temperature
At Point of Use 110+
At Heater

Temperature of City Water

Date of Water Heater
Date of Installation

Is the tank warm to the touch? ☐ Yes ☑ No
Are pipes insulated at least 3' from heater? ☐ Yes ☑ No
Any signs of leakage? ☐ Yes ☑ No
Requires maintenance? ☐ Yes ☑ No
Is the tank wrapped? ☐ Yes ☑ No
Do obstructions prevent wrapping? ☑ Yes ☐ No

Distance from Heater to Furthest Point of Use:

Hot Water Uses Other than Lavatories:

WATER CONSUMPTION

Fixture Type	Quantity	Gal/Flush	Gal/Min	Low-Flow?	Aerators?
Water Closets (tank)	0				
Water Closets (valve)	28				
Urinals	8				
Lavatories	14				
Service Sinks	9				
Showers	0				
Electric Water Coolers	11				
Dishwashers	1				
Hose Bibs	--				

Exhaust Fans tied to Lights? ☐ Yes ☑ No

HW Temperature = 110+ °F

CW Temperature = ~50 °F

Large Water Consumption Scenarios

	Yes	No	Time Period of Water Usage	Estimated Amount
Watered the playing field	x		Summer 2012	
Other: ______________				

SPECIALTY EQUIPMENT

Item	Yes / No	Quantity
Refrigerators	Y	6
Mini-Fridges	Y	2
Freezers	Y	2
Walk-In Refrigerators	N	
Walk-In Freezers	N	
Microwaves	Y	3
Mixers	Y	1
Ranges	Y	1
Ovens	Y	3
Dishwashers	Y	1
Hoods w/ Exhaust Fans	Y	1
Carafe Warmer	Y	2
Coffee Makers	Y	1
Pop Machines	Y	2
Vending Machines	N	
Ice Makers	N	
Space Heaters	N	
Copiers	Y	1
Fax Machines	N	
Scanners	N	
Printers	Y	22
Printer/Fax/Scan/Copy Machines	Y	2
Plotters	N	
Laminator	Y	1
Exhaust Fans (Separate from Light)	Y	4
Computers	Y	56
Projector	Y	12
Smartboard	Y	12
Overhead Machine	Y	3
TV	Y	5
Ceiling Fans	Y	47
Movable Fans	Y	8
Electronic Keyboard	Y	1

Lighting

INTERIOR

Building Area	Fixture Type	# of Fixtures	Watts per Fixture	Ballast
Linear T12 Fluorescent Fixtures, 2- Lamp		359	68 W	Magnetic
Incandescent Fixtures		11	100 W	n/a

EXTERIOR

Building Area	Fixture Type	# of Fixtures	Watts per Fixture	Ballast

Fixture Types:

Incandescent

Fluorescent

Mercury Vapor

High Pressure Sodium

Low Pressure Sodium

Metal Halide

Are lights on in unoccupied areas? ☑ Yes ☑ No

Is the exterior lighting on during the day? ☐ Yes ☑ No

How are lights operated?
☑ Toggle Switches (For Inside Lighting)
☐ Occupancy Switches
☐ Photovoltaic/Daylight Sensors
☐ Other ______

Building Audit Photographs

Figure A-1 Room Temperature Sensor

Figure A-2 Typical Classroom

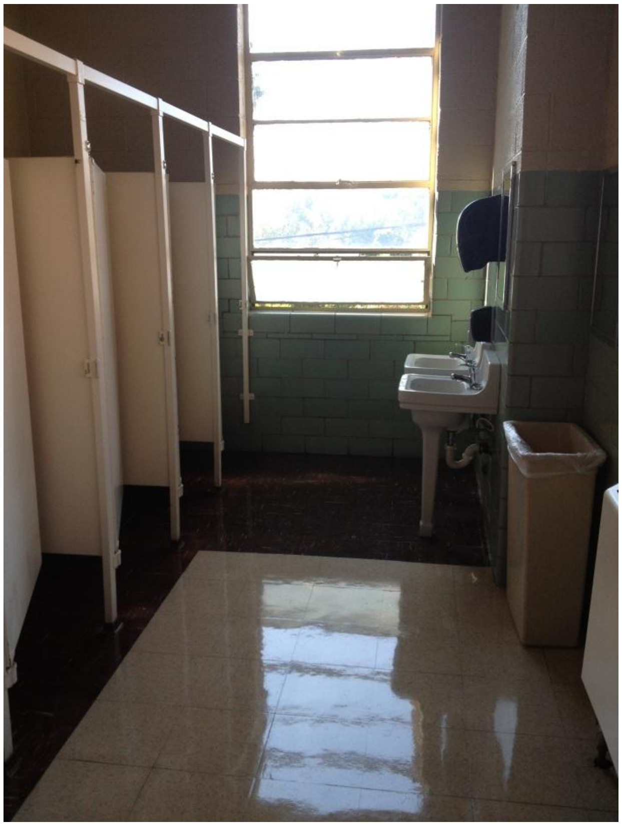


Figure A-3 Typical Restroom

Figure A-4 Typical Restroom Water Closet

Figure A-5 Typical Restroom Urinals

Figure A-6 Double Door Vestibule

Figure A-7 Energy Conservation Reminder

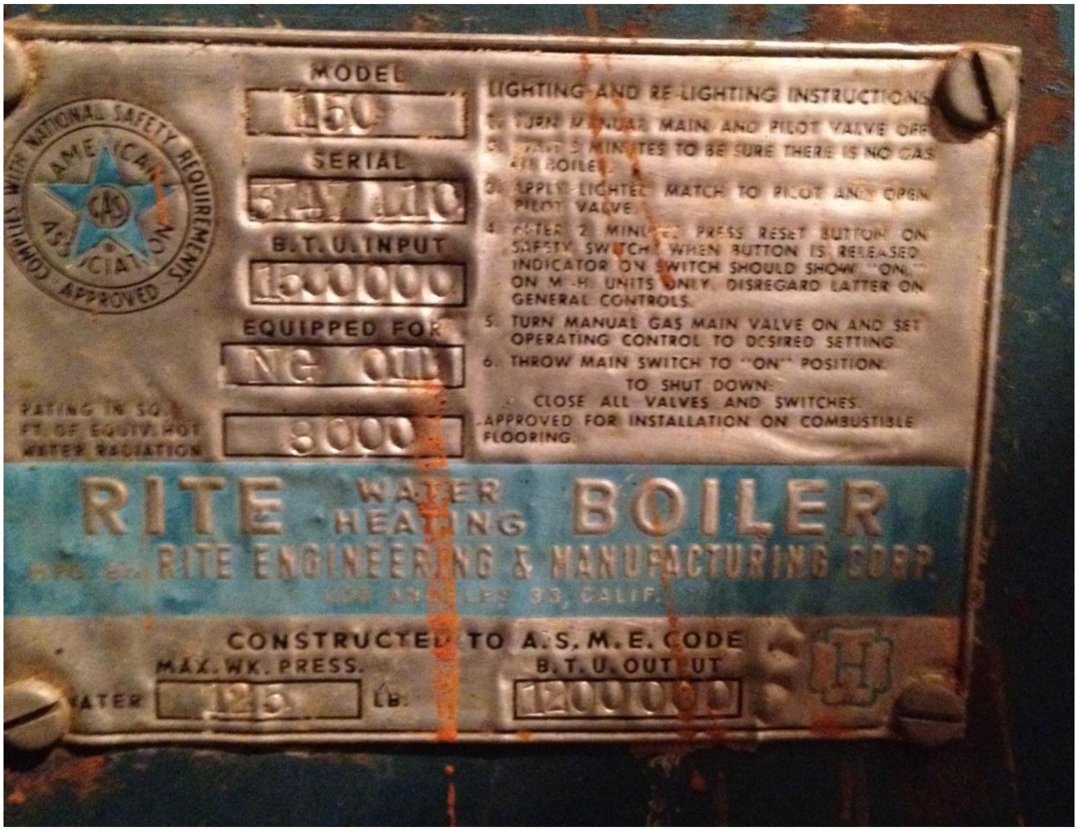


Figure A-8 Boiler 1 Name Plate

Figure A-9 Boiler 1 Degradation

Nº 150M

PUMP CONTROL & LOW WATER CUT-OFF
MAXIMUM BOILER PRESSURE 150 PSI
PUMP & CUT-OFF CIRCUITS-AMPERE RATING

MOTOR DUTY	115 VAC	230 VAC	115 VDC	230 VDC
FULL LOAD	7.4	3.7	2.4	1.2
LOCKED ROTOR	44.4	22.2	24.0	12.0

PILOT DUTY SERVICE 345 VOLT AMPS, 115V & 230 VAC
ALARM CIRCUITRY

AC 1 AMP / DC 1/2 AMP 115 VOLTS
AC 1/2 AMP / DC 1/4 AMP 230 VOLTS

USE COPPER WIRE ONLY

LIMIT CONTROL
LISTED 330M

APPROVED

NOTE: OPEN [illegible] AND FLUSH OUT FLOAT CHAMBER AT LEAST ONCE EACH DAY WHEN BOILER IS IN OPERATION.

ITT McDonnell & Miller
ITT Fluid Technology Corporation
3500 N. SPAULDING AVE • CHICAGO, IL 60618

Figure A-10 Boiler Pump Name Plate

Figure A-11 Boiler 150 Degree Temperature Setting

Figure A-12 Water Heaters

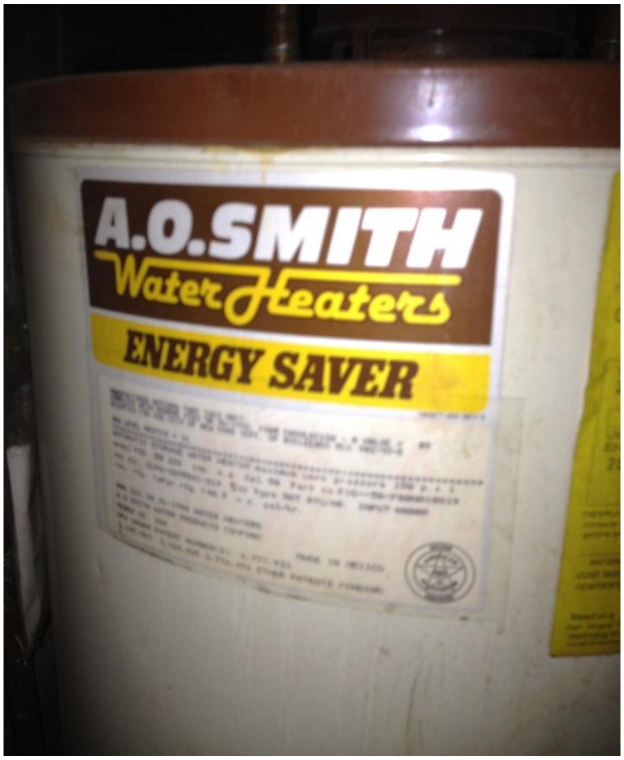


Figure A-13 Water Heater 1

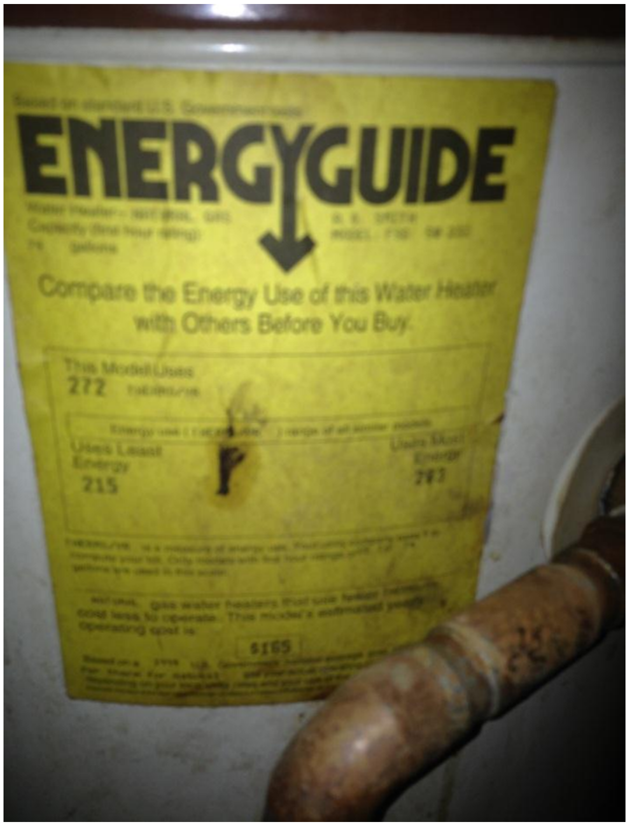
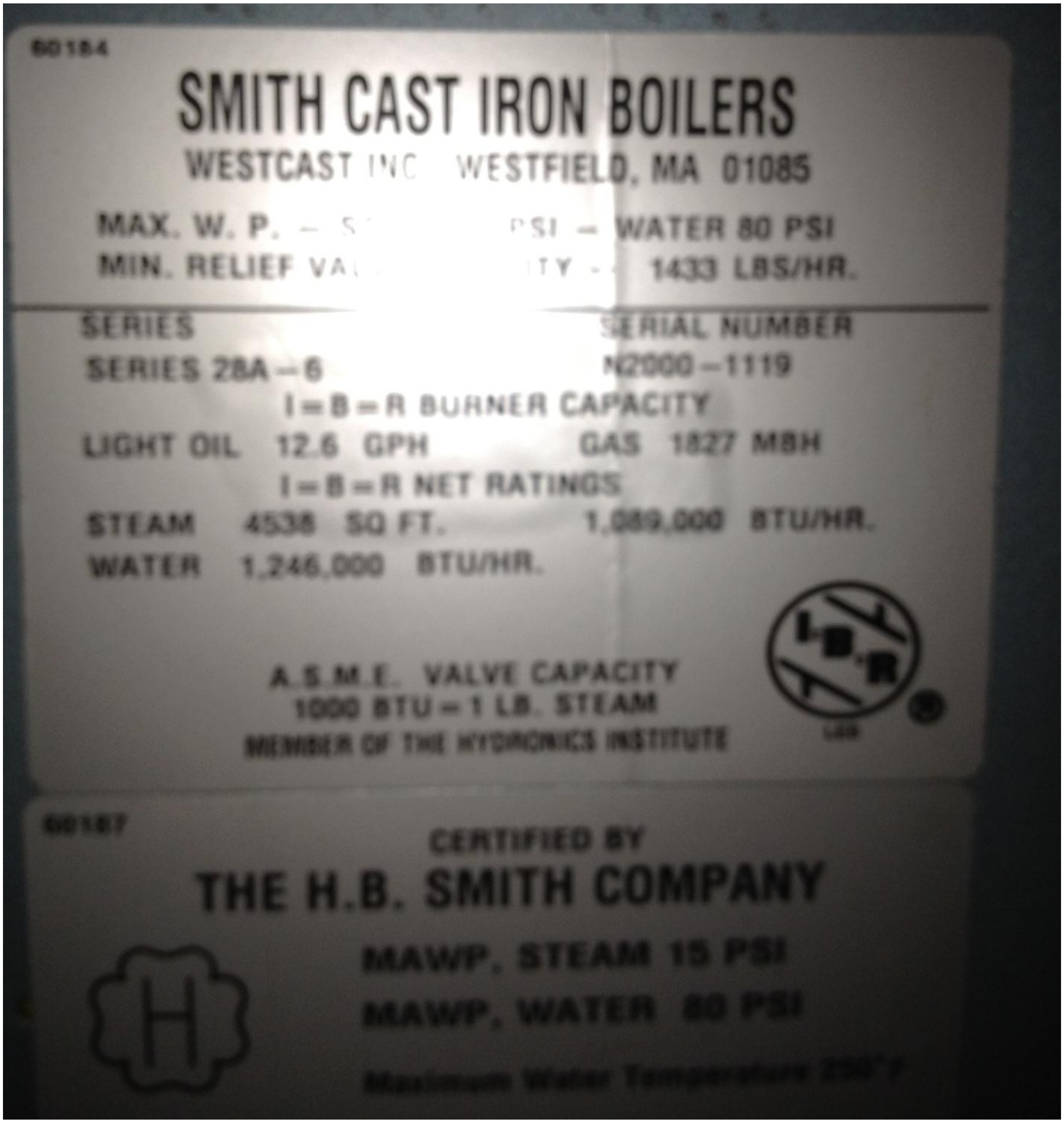


Figure A-14 Water Heater 1 Energy Star Label

Figure A-15 Water Heater 2

Figure A-16 Water Heater 2 Energy Star Label



60184

SMITH CAST IRON BOILERS

WESTCAST INC WESTFIELD, MA 01085

MAX. W. P. – S [illegible] PSI – WATER 80 PSI

MIN. RELIEF VA [illegible] ITY – 1433 LBS/HR.

SERIES	SERIAL NUMBER
SERIES 28A–6	N2000–1119

I=B=R BURNER CAPACITY

LIGHT OIL 12.6 GPH GAS 1827 MBH

I=B=R NET RATINGS

STEAM 4538 SQ FT. 1,089,000 BTU/HR.

WATER 1,246,000 BTU/HR.

A.S.M.E. VALVE CAPACITY

1000 BTU = 1 LB. STEAM

MEMBER OF THE HYDRONICS INSTITUTE

60187

CERTIFIED BY

THE H.B. SMITH COMPANY

MAWP, STEAM 15 PSI

MAWP, WATER 80 PSI

Maximum Water Temperature 250°F

Figure A-17 Boiler 2 Name Plate

Figure A-18 Fan Coil Unit in Office Area Near Kitchen

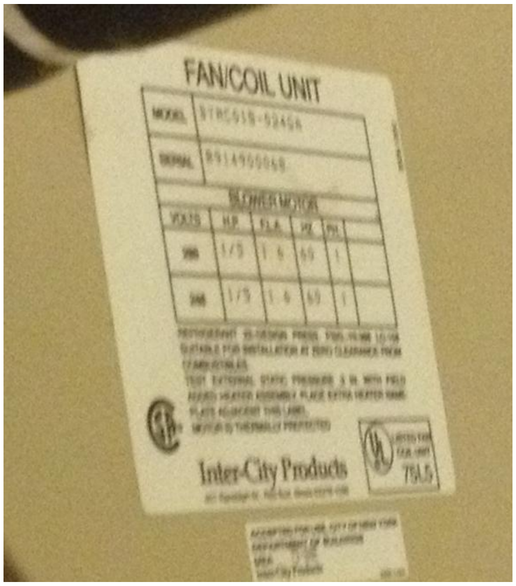


Figure A-19 Fan Coil Name Plate

Figure A-20 Fan Coil Thermostat

Figure A-21 Kitchen Chafing Dish Warmer

Figure A-22 Kitchen Stove with Hood

Figure A-23 Kitchen Oven

Figure A-24 Kitchen Pan Warmer

Figure A-25 Kitchen Dishwasher

Figure A-26 Kitchen Stand Mixer

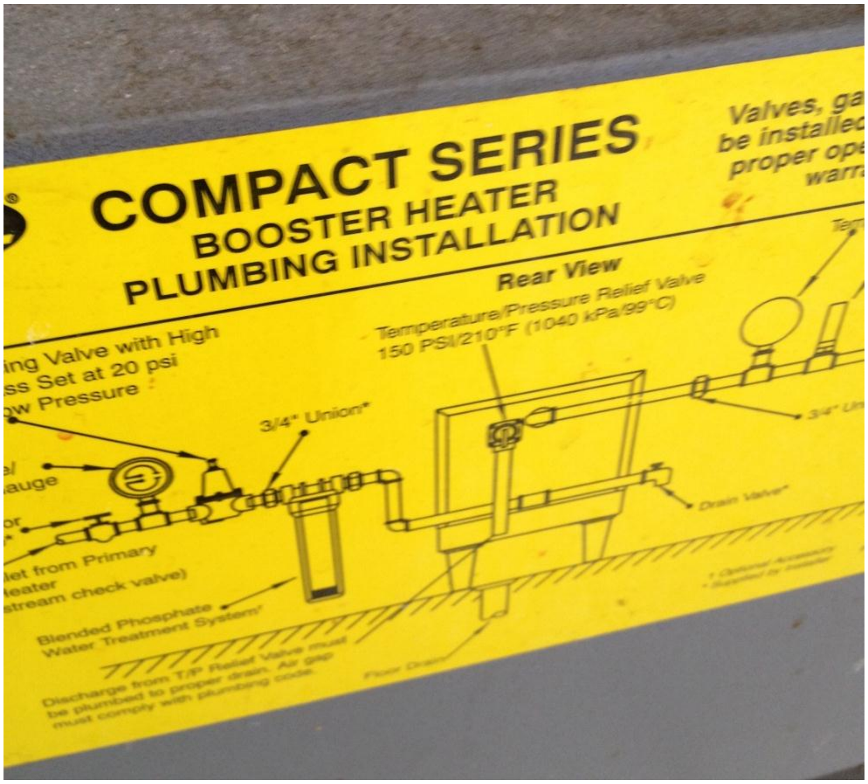


Figure A-27 Kitchen Booster Heater Label

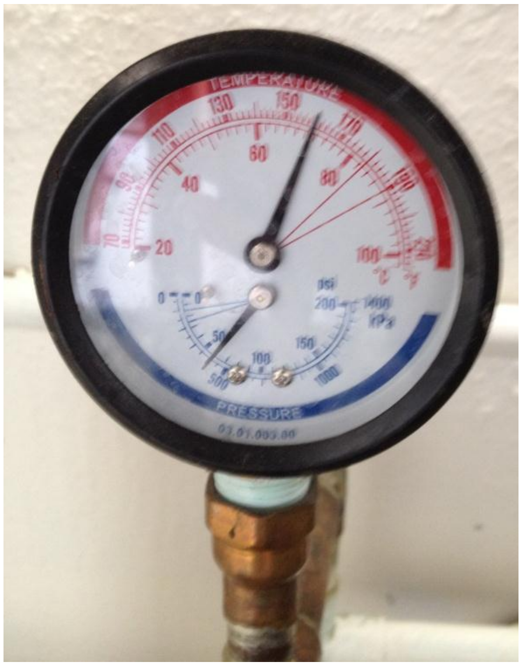


Figure A-28 Kitchen Booster Heater 160 Degree Temperature Setting

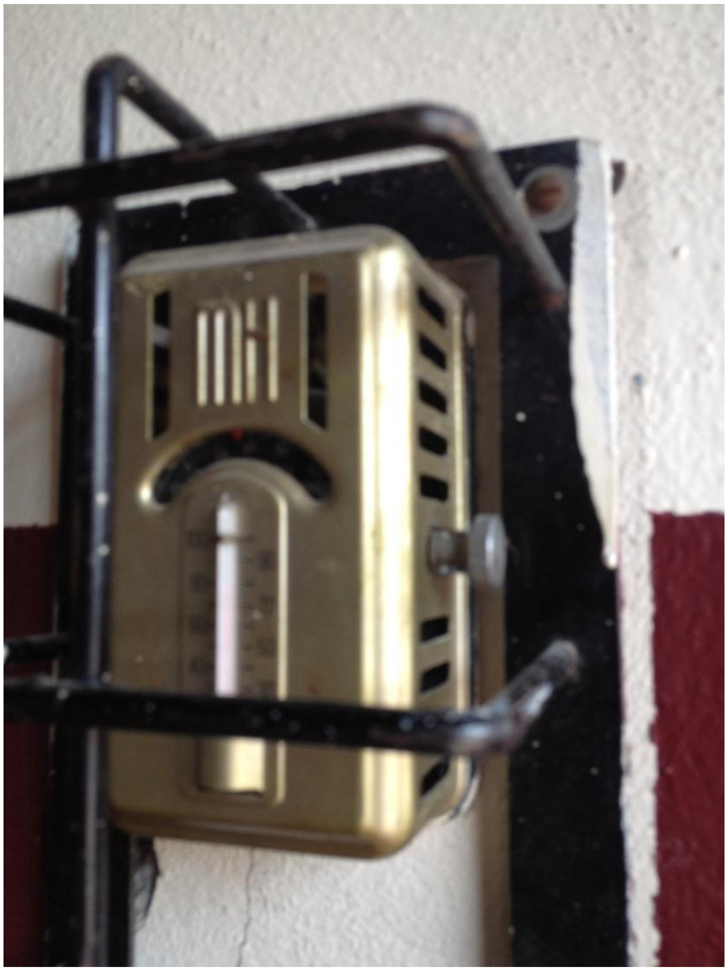


Figure A-29 Gymnasium Temperature Sensor

Building Audit Checklist

LIGHTING		Problem?		Recommended?	
		Yes	No	Yes	No
1. Incandescent lamps are used in office, workrooms, hallways, and gymnasiums.			x		
a.	Where possible use a single incandescent lamp of high wattage rather than two or more smaller lamps of combined wattage.				x
b.	Discontinue using extended service lamps except in special cases such as recessed directional lights where short lamp life is a problem.				x
c.	Discontinue using multi-level lamps. The efficiency of a single wattage lamp is higher per watt than a multi-level lamp.				x
d.	Replace non-decorative incandescent lamps with more energy conserving types such as fluorescents in general purpose areas and HIDs in large group areas.				x
2. Lamps and fixtures are not clean.			x		
a.	Establish a regular inspection and cleaning schedule for lamps and fixtures. Dust buildup reduces effectiveness.				x
b.	Replace lens shielding that has turned yellow or hazy with new acrylic lenses which do not discolor.				x
c.	Replace outdated or damaged fixtures with modern type fixtures that are easy to clean.				x
3. Lamps are replaced individually as they burn out.		x			
a.	Establish a group relamping schedule. Lamp manufacturer's sales offices can provide a computerized relamping schedule at minimal to no cost.			x	
4. Ceilings and other room surfaces have reduced reflectivity due to dirt.			x		
a.	Clean surfaces.				x
b.	When repainting or recovering, use coatings or coverings with good reflectance.				x
5. Daylighting is not used effectively.		x			
a.	Locate work stations requiring high illumination adjacent to windows.			x	
b.	Switch off lights when daylight is sufficient.			x	
c.	Clean windows and skylights.			x	
d.	Install light sensors and dimming equipment which automatically compensate for varying natural lighting conditions.			x	

LIGHTING		Problem?		Recommended?	
		Yes	No	Yes	No
6. Decorative lighting is excessive and/or not controlled optimally.			x		
a.	Replace burned out lamp with lower wattage lamps.				x
b.	Establish schedule for manual control or control operation with existing photoelectric or time clock controls if practical.				x
7. In fixtures where fluorescent lamps have been removed, the ballasts have not been disconnected.			x		
a.	Disconnect ballasts.				x
8. Lighting is on in unoccupied areas.		x			
a.	Post instructions to turn off lights when leaving area.			x	
b.	Identify areas being controlled by gang switches.			x	
c.	Assure wall switch timers function properly.				x
d.	Provide timer switches/occupancy switches in remote ot seldom used areas where there will be brief occupancy periods.			x	
9. Security/outdoor lighting is not automatically controlled and/or lighting levels are excessive.			x		
a.	Replace burned out lamps with lower wattage lamps.				x
b.	Establish manual operation schedule considering change in daylight with season.				x
c.	Control lighting with existing photoelectric or time-clock controls if practical.				x
d.	Eliminate outdoor lighting where practical.				x
e.	Replace exterior incandescent lamps with more efficient types such as High Pressure Sodium or Metal Halide.				x
10. Deep baffled downlighting fixtures have conventional "R" reflector lamps installed.			x		
a.	Replace burned out "R" lamps with elliptical reflector "ER" lamps which yield approximately the same average light level for half the energy cost.				x
11. Two lamps have not been removed from four-lamp fixtures where possible.			x		
a.	Remove two lamps and disconnect ballasts.				x

POWER		Problem?		Recommended?	
		Yes	No	Yes	No
1. Transformers remain energized when serving no load for extended periods.			x		
a.	Disconnect transformer.				x
2. Transformer ambient temperature is high.			x		
a.	Assure that a forced ventilation system serving the space is functioning or that a natural ventilation system's openings are not				x
3. Vending machines remain energized during unoccupied periods.		x			
a.	Provide manual operation schedule or connect to existing time clocks or programmable controllers.			x	
4. Refrigerator drinking fountains or recirculating chilled drinking water systems are not controlled for occupancy.		x			
a.	Provide manual operation schedule or connect to existing time clocks or programmable controllers.			x	
5. Elevator operation is not optimized for occupancy variations.			x		
a.	Consult with manufacturer for possible operating changes.				
6. Lubricants used on major rotating equipment with high load factors have not been optimized for reduction of friction losses.			x		
a.	Consult with equipment manufacturers and lubricant manufacturers to determine if lubricant change is cost-effective.				x
7. Substantial electricity demand charges are incurred.			x		
a.	Determine is use of major electrical equipment can be scheduled to reduce demand.				x

BUILDING ENVELOPE		Problem?		Recommended?	
		Yes	No	Yes	No
1. Improper alignment/operation of windows and doors allows excessive infiltration.		x			
a.	Realign or re-hang windows or doors that do not close properly. In extreme cases, consider permanent sealing of windows.				x
b.	Make sure automatic door closing mechanisms work properly.			x	
c.	Replace or repair faulty gaskets on all doors.			x	
d.	Resize exterior doors. (Make delivery doors smaller to reduce infiltration)				x
e.	Add expandable separate enclosures, where practical.				x
f.	Install self-closing doors on openings to unconditioned spaces.				x
g.	Install a switch on overhead doors that prevent activation of heating and cooling units when doors are open.				x
h.	Install vestibule doors at major entrances.				x
2. Weather-stripping and/or caulking around all areas of infiltration is worn, broken or missing.		x			
a.	Replace worn and/or broken weather stripping and caulking.			x	
b.	Replace broken or cracked windows.			x	
3. Doors and/or windows separating conditioned from non-conditioned areas are left open.			x		
a.	Assure that automatic door closers function properly.				x
4. Excessive expanses of glass exist on exterior walls.		x			
a.	When replacing windows, replace with thermopanes, utilizing the same casings.			x	
b.	Keep curtains and drapes closed in unoccupied spaces.				x
c.	Totally or partially insulate non-operable windows.			x	
d.	Consider adding reflective or heat absorbing film to minimize solar gain.			x	
e.	Install double-pane windows.			x	
f.	Install adjustable outdoor shading devices.			x	
g.	Attach storm glazing to moveable sash of operable windows.			x	

BUILDING ENVELOPE		Problem?		Recommended?	
		Yes	No	Yes	No
5. There is no insulation between conditioned and unconditioned spaces.		x			
a.	Insulate between heated/cooled spaces and unconditioned or outside areas.			x	
6. Ceiling/roof insulation is inadequate or has been water damaged.			x		
a.	Before replacing water damaged insulation, repair roof where required.				x
b.	Verify that vapor barrier faces the conditioned space and is intact.				x
c.	Add new insulation to meet recommended standard.				x
7. Blinds and Curtains are not used to help insulate the building.		x			
a.	Instruct personnel to close interior shading devices.				x
b.	Repair or replace damaged/missing shading devices.				x
c.	Add reflective or absorbing films to reduce solar gains.			x	
d.	Install outdoor shading devices.			x	

HVAC		Problem?		Recommended?	
		Yes	No	Yes	No
1. Air filters and heating/cooling coils do not receive scheduled maintenance.			x		
a.	Develop maintenance schedule.				x
b.	Install filter pressure-drop gauges.				x
2. Duct or pipe insulation is damaged or missing.		x			
a.	Repair.			x	
b.	Replace.			x	
c.	Protect.			x	
3. Fan drive belts deflect excessively.			x		
a.	Adjust fan belt tension.				x
4. Air leaks from ducts and plenums are noticeable.			x		
a.	Repair leaks.				x
5. Air inlets and outlets are dirty or obstructed.			x		
a.	Clean				x
b.	Remove obstruction				x
c.	Remove access covers and inspect turning vanes, fire dampers, and splitters.				
6. Boiler combustion effiency is not tested on a scheduled basis.		x			
a.	Prepare testing schedule and log of test results.			x	
b.	Conduct combustion effiency test.			x	
7. Boilers are not maintained on a scheduled basis.		x	x		
a.	Perform maintenance per manufacturer's instructions.			x	

HVAC		Problem?		Recommended?	
		Yes	No	Yes	No
8. Multiple boilers or heaters fire simultaneously.			x		
a.	Adjust controls so that boiler #2 will not fire until boiler #1 can no longer satisfy the demand.				x
b.	Purchase and install automatic staging controls, if applicable.				x
9. Stack temperature appears excessively high (greater than 400°F plus room temperature).			?		
a.	Ensure that proper amount of air for combustion is available in furnace room.			x	
b.	Examine and clean air intake filters.			x	
c.	Perform flue gas analysis on a regular basis to ensure proper air to fuel ratio.			x	
d.	If furnace is over-firing, verify that spuds and nozzles are properly sized. Also check that fuel pressures are not too high.				x
e.	Purchase a kit for flue gas analysis if frequent testing is anticipated.			x	

HVAC - CONTROLS		Problem?		Recommended?	
		Yes	No	Yes	No
1. Thermostats on heating/cooling units are vulnerable to occupant adjustment.			x		
a.	Reset thermostats to correct settings.				x
b.	Install or replace locking screws to prevent tampering.				x
c.	Install tamper-proof locking covers on thermostats.				x
2. Space temperatures are higher or lower than thermostat settings.		x			
a.	Recalibrate thermostat.			x	
b.	Blow out moisture, oil and dirt form pneumatic lines; clean contacts if electrical control system.				x
c.	Recalibrate controllers.				x
d.	Ensure that control valves and dampers are modulated properly.			x	
e.	Make sure that air intake volume is not excessive.				x
3. Thermostat settings have not been adjusted for change in seasons.			x		
a.	Adjust thermostats to 68°F in heating season, and 78°F during cooling season.				x
b.	Change the location of thermostats from areas subject to extreme temperature flucuations, such as next to window, or over a heating or cooling unit.				x
4. Control devices are not inspected on a regular basis.			x		
a.	Routinely check all time clocks and other control equipment for proper operation.				x
5. Building temperatures are not adjusted for unoccupied periods.		x			
a.	Reduce thermostat settings by a minimum of 10°F at nights, weekends and holidays during heating season.			x	
b.	Shut down air conditioning units at night, on weekends, holidays.			x	
c.	Install automatic controls such as time clocks or an automated management system.			x	
6. Unoccupied or little used areas are heated or cooled unnecessarily.		x			
a.	Reduce winter thermostat settings to 55°F in unoccupied areas.			x	
b.	Increase summer thermostat setting, if possible.			x	

HVAC - HEATING		Problem?		Recommended?	
		Yes	No	Yes	No
1. Water in heating system is heated when there is no need.		x			
a.	Turn off boiler, pumps or heat source.			x	
b.	Install control to automatically shut down heat generating device when outside air temperature reaches 60°F.			x	
2. Condensate from street stream is being discharged to sewer drain.			x		
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.				x
3. Heating pilot lights are on during the cooling season.			?		
a.	Turn pilots off.			x	
b.	Replace worn units with new electronic ignition models to avoid unnecessary fuel consumption.			x	
4. Steam radiators or other steam equipment fails to heat, or is operating erratically.			x		
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. Initiate a stream trap maintenance program.				x
b.	Clean or replace thermostatic control valves on radiators.			x	
c.	Check air vent valve. If not operating properly, replace.			x	
d.	If thermostatic trap is malfunctioning, clean or replace bellows element.				x
e.	Water pockets may be obstructing steam flow. Correct by re-pitching or rerouting pipes.				x
5. Steam, condensate and heating water piping insulation is in disrepair or missing.			x		
a.	Inspect pipes for broken or missing insulation. Repair or replace as needed.				x
b.	Install additional pipe insulation in accordance with design specifications and energy conservation codes.				x

HVAC - HEATING		Problem?		Recommended?	
		Yes	No	Yes	No
6. Operation of oil burner is accompanied by excessive smoke and sooting.		☐	x		
a.	Inspect burner nozzles for wear, dirt and incorrect spray angles. Clean and adjust as necessary.			☐	x
b.	Verify that oil is flowing freely and that oil pressure is correct.			☐	x
c.	Perform flue gas analysis to set proper air to fuel ratio.			☐	x
d.	If burning heavy oil, check oil temperature.			☐	x
e.	If steam atomizing burners, check steam-oil differential pressure.			☐	x
f.	Pressure kit for flue gas analysis if frequent testing is anticipated.			☐	x
g.	Purchase new burner nozzles or tips.			☐	x
7. Soot and odors are detected in areas where they are not exposed.		☐	x		
a.	Heat exchanger may have burned out. Replace.			☐	x
b.	Stack draft may be inadequate. Clean and correct as necessary.			☐	x
c.	Perform flue gas analysis to obtain proper air to fuel ratio.			☐	x
d.	Check operation of furnace draft controller.			☐	x
e.	Check boiler setting for leaks.			☐	x
8. Evidence indicated faulty or inefficient boilers or furnaces.		☐	x		
a.	Remove scale deposits, accumulation of sediment and boiler compounds on water side surfaces.			☐	x
b.	Remove soot from tubes.			☐	x
c.	Observe the fire when the unit shuts down. If the fire does not cut off immediately, it could indicate a faulty solenoid valve.			☐	x
d.	Inspect all boiler insulation, refractory, brick work and boiler casing for hot spots and air leaks. Repair and seal as necessary.			☐	x
e.	Replace dangerous or ineffective units with more efficient modular type units.			☐	x
9. Air is humidified.		☐	x		
a.	Discontinue or reduce humidification where possible.			☐	x

HVAC - HEATING		Problem?		Recommended?	
		Yes	No	Yes	No
10. Burner short-cycles.			x		
a.	Start-stop limit switches may be set too closely. Reset as required.				x
b.	Thermostat may be faulty.				x
c.	Employ control specialist to adjust control.				x
11. Combustion air to boiler/furnace is not preheated.			x		
a.	Utilize heat from flue gas to preheat combustion air by means of a heat recovery device.				x
b.	Consider economizer to transfer heat from flue gas to feed water.				x
c.	Consider heat recovery from continuous blowdown.				x
12. Hot water radiation units fail to operate.			x		
a.	Radiators are air-locked. Open air vents and bleed off air until water appears.				x
b.	Bleed off water in pneumatic air lines if necessary. Check for air leaks.				x
c.	Repair or replace faulty thermostats.				x
d.	Hot water pump or booster pump may not be functioning. Repair or replace as necessary.				x
13. Radiators, convectors, baseboards and finned-tube heaters are not providing sufficient heat.		x			
a.	Boiler temperature may have dropped. Correct as necessary.			x	
b.	Bleed air from units.			x	
c.	Establish a systematic cleaning schedule.			x	
d.	Remove items obstructing discharge grilles.			x	
e.	Bleed off water in pneumatic air lines if necessary. Check for air leaks.			x	
f.	Repair faulty valves.			x	
g.	Repair or replace faulty thermostats.			x	
h.	Hot water pump or booster pump may not be functioning. Repair or replace as necessary.			x	

HVAC - HEATING		Problem?		Recommended?	
		Yes	No	Yes	No
14. Condensors and cooling towers are not maintained on a scheduled basis.			x		
a.	Prepare maintenance schedule. Perform maintenance per manufacturer's recommendations.				x
b.	Maintain cooling tower water.				x
15. Circulating pump operation is manually controlled.			x		
a.	Develop operating schedule.				x

HVAC - COOLING		Problem?		Recommended?	
		Yes	No	Yes	No
1. Multiple air conditioning compressors start simulatneously.			x		
a.	Adjust controls to stage compressors.				x
b.	Should automatic controls not exist, puchase and install. This will allow compressor #2 to cut in when compressor #1 can no longer satisfy space conditioning load.				x
2. Chiller evaporating and condensing temperatures are not optimized.			x		
a.	Increase chiller evaporator temperature following manufacturer's recommendations.				x
b.	Decrease chiller condensing temperature following manufacturer's recommendations.				x
3. Reheat coils are used to maintain zone temperatures.			x		
a.	Convert to variable air volume system if the reheat coils are not necessary to supply heat during the heating season.				x
4. Building utilizes a dual duct or multizone system.			x		
a.	Convert dual duct or multizone systems to variable air volume, if buildign has a separate heating season.				x
b.	Install controls to automatically reset hot and cold deck temperatures.				x
5. Air conditioning load trips circuit breaker on extremely warm days.			x		
a.	Tighten wire lugs if loose.				x
b.	Replace defective circuit breakers.				x
c.	Clean condensor on air cooled systems.				x
d.	Clean scale build-up in condensor on water cooled systems.				x

HVAC - COOLING		Problem?		Recommended?	
		Yes	No	Yes	No
6. Air of inadequate volume or temperature is being discharged through grilles.			x		
a.	Defrost evaporative coil if iced. Determine cause if icing and correct.				x
b.	Clean evaporator coil, fins and tubes.				x
c.	Clean or replace air filters.				x
d.	Fire damper may be closed. Open and replace fusible link if necessary.				x
e.	Balancing damper may have slipped and closed. Open to correct position and tighten wing nut.				x
f.	If fan is rotating backwards, reverse rotation by reversing electrical contacts.				x
g.	Clean condensor coil and/or water tower nozzles.				x
h.	Install differential pressure-sensing switches to alarm when air flow drops significantly.				x
7. Refrigeration condensors or coils are dirty, clogged and/or not functioning efficiently.			x		
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.				x
b.	Increased system pressure may be due to dirty condensors which will decrease system efficiency. High discharge temperatures are often caused by defective or broken compressor valves. Repair or adjust as required.				x
c.	Inspect the liquid line leaving the strainer. If it feels cooler that 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.				x
d.	Clean coils and/or other elements as needed on a scheduled basis. Include dehumidification coils.				x
8. Chilled water piping, valves and fittings are leaking.			x		
a.	Repair joint or piping leaks.				x
b.	Repair or replace valves.				x
9. Chiller operation is not optimized (Listen for short-cycling).			x		
a.	Raise chilled water supply temperature.				x
b.	Remove scale deposits from condensors.				x
c.	Check refrigerant charge.				x

HVAC - COOLING		Problem?		Recommended?	
		Yes	No	Yes	No
10. Refrigeration compressor short-cycles.			x		
a.	Refrigerant charge is low or refrigerant is leaking. Find and repair leak. Recharge system.				x
b.	Repair electrical control circuit if required.				x
c.	Reset high/low pressure control differential settings if needed.				x
d.	Evaporation coil may be iced up or dirty. Defrost and clean.				x
e.	Liquid line solenoid valve may be leaking.				x
f.	If frost is detected on the liquid line strainer, it is clogged. Clean strainer.				x
g.	Clean condensor coil.				x
h.	If condensor is a cooling tower, ascertain if spray nozzles are plugged. Make sure water flow is unobstructed. Clean towers of leaves and debris.				x
i.	Remove scale deposits from shell/tubes on water condensors.				x
j.	Repair suction valves in compressor, if needed.				x
11. Multiple parallel chillers have no isolation schedule for extended light-load operation.			x		
a.	Develop load vs. capacity matrix.				x
b.	Isolate unneeded chillers.				x
12. Steam, hot or chilled water leaks are evident.			x		
a.	Repair leaks.				x
13. Steam, hot or chilled water valves do not shut off tight.			x		
a.	Repair or replace valve.				x

HVAC - VENTILATION		Problem?		Recommended?	
		Yes	No	Yes	No
1. Air flow to space feels unusually low is unconsistent from one space to another.		x			
a.	Utilize ductwork access opening to check for any obstructions such as loose hanging insulation, loose turning vanes and				x
	accessories, and closed volume or fire dampers. Adjust, repair, or replace as necessary.				
b.	Inspect all room outlets and inlets. They should be kept clean and free of all dirt and obstructions.			x	
c.	Clean or replace dirty or ineffective filters on a regular basis.				x
d.	Post signs instructing occupants not to place objects where they will obstruct air flow.			x	
e.	Rebalance system.				x
2. Large spaces having low occupancy are maintained at comfort conditions.			x		
a.	Reduce thermostat settings in winter, raise settings in summer.				x
b.	Consider regrouping activities into smaller areas which can be conditioned separately from remainder of buildign.				x
3. Heating/cooling equipment is operating in lobbies, corridors, vestibules, and/or other public areas.		x			
a.	Lower heating set points in the above areas if there is no possibility of freeze-up.			x	
b.	Properly adjust and balance air/water systems and controls.				x
4. An excessive quantity of outdoor air is used to ventilate the building.			x		
a.	Reduce outdoor air quantity to the minimum allowed by codes by adjusting outdoor air dampers.				x
b.	Repair any malfunctioning ventilation equipment.				x
c.	Replace old-style dampers with new high quality opposed-blade models with better close-off ratings.				x
d.	Repair leaking or faulty dampers.				x

HVAC - VENTILATION		Problem?		Recommended?	
		Yes	No	Yes	No
5. Outdoor air intake dampers open when building is unoccupied.			x		
a.	Close outdoor air dampers when building is unoccupied. Be sure dampers have proper seals.				x
b.	Install controls which will automatically close dampers during unoccupied periods.				x
6. Return, outdoor air and exhaust dampers are not sequencing properly.			x		
a.	Adjust damper linkage.				x
b.	Be sure damper motors are operating properly.				x
c.	Readjust position indicators to accurately indicate damper positions.				x
d.	Reset linkage, repair or replace dampers if blades do not close tightly.				x
e.	Replace old-style dampers with new high quality opposed-blade models with better close-off ratings.				x
7. Ventilation systems are not utilized for natural cooling capability.		x			
a.	Whenever possible, use outdoor air for cooling rather than using refrigeration.			x	
b.	Install an economizer cycle with enthalpy control to optimize use of outside air for cooling.				x

DOMESTIC HOT WATER		Problem?		Recommended?	
		Yes	No	Yes	No
1. Hot water temperature is excessive.		x			
a.	Lower thermostat or controller set point to 105-115 °F for general purposes.			x	
2. System insulation is damaged or missing.		x			
a.	Repair, replace. Protect to prevent recurrence of damage.			x	
3. Water temperatures are not reduced during unoccupied periods.		x			
a.	Schedule setbacks (either manually or with existing time clock). Consider schedule's impact on electrical demand.			x	
b.	Install an appropriate automatic control device.			x	
4. Water leaks are evident.			x		
a.	Repair leaks and defective faucets.				x
5. Heat pump water heater coils are not maintained on scheduled basis.			x		
a.	Schedule maintenance following manufacturer's recommendations.				x
6. Hot water recirculating pumps run continuously.			x		
a.	Develop operating schedule to match occupancy.				x
7. Drips or leaks are evident in hot water systems.			x		
a.	Repair all leaks including those of the faucets and pumps.				x

DOMESTIC HOT WATER		Problem?		Recommended?	
		Yes	No	Yes	No
8. Electric water heater has no time restrictions on heating cycle.			x		
a.	Utilize "vacation cycle" on water heater when not needed during extended periods. (Note: Complete deactivation could cause leaks)				x
b.	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 loads.				x
9. Devices to conserve heated water have not been utilized where practical.		x			
a.	Install mixing valves.				x
b.	Replace standard faucets with self-closing, flow restrictor valves.			x	
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.				x
10. Storage tanks, piping and water heaters are utilized inefficiently.			x		
a.	Install a small domestic hot water heater to maintain desired temperature in water storage tank.				x
b.	Install de-centralized water heating.				x

BUILDING OCCUPANCY		Problem?		Recommended?	
		Yes	No	Yes	No
1. Off-hour activities extend operating hours for energy using systems.		x			
a.	Reschedule off-hour activities to accommodate partial shutdown of building.			x	
b.	Reschedule custodial and cleaning activities during working hours whenever possible.			x	
2. Building has extended occupancy areas such as computer rooms.			x		
a.	Isolate these spaces from the portion of the building having fewer operating hours.				x

Appendix B - Audit Worksheets

Pre-Audit

1. Two weeks prior to audit, send owner survey to contact person and request to have it returned at least two days prior to the audit.
2. Update audit documents to reflect the owner survey.
3. If available, use building floor plans to fill out as much of the paperwork as possible prior to audit.
4. Become familiar with the floor plans.
5. Develop a list of questions and unknowns to ask contact person. Examples:
    a. What are the common occupancy hours?
    b. How many occupants are there normally?
    c. Are there any energy saving measures currently implemented?
    d. When was the last remodel/upgrade?
6. Assemble all items needed for the audit: flashlight; digital camera; yardstick(s); thermal camera (if available); 4-in-1 device(s): thermometer, light meter, hygrometer, and anemometer; highlighters; floor plans; clipboards; writing utensils; and blower door test.

Audit

1. Meet with owner/representative/contact person and discuss audit procedure and ask questions.
2. Take a brief tour of the facility.
    a. Note major building equipment and attributes.
        i. HVAC equipment
        ii. Fans
        iii. Restrooms
        iv. Mechanical and electrical rooms
        v. Access to roof/storage areas/equipment areas
3. Start with one specific task and work through others.
4. Be sure to take notes and photos.
    a. HVAC

        i. Note: manufacturer, type of equipment
        ii. Heating/Cooling Source, examples:
            1. Electricity
            2. Natural gas
            3. Fuel oil
            4. Hot/Chilled water
            5. Steam
        iii. Take photos of name plates, equipment and location.
    b. Room Conditions
        i. Note any nonoperational lamps/fixtures.
        ii. Record data for each room.
            1. Number of fixtures
            2. Number of lamps
            3. Light level at center of the room at consistent height (use yardstick as a standard)
            4. Room temperature and relative humidity
            5. Thermostat set point
            6. Review the thermostat programmed set points
    c. Plumbing
        i. Record hot and cold water discharge temperatures.
        ii. Record hot water heater data and take photos.
        iii. Document all pumps (i.e. recirculation pumps).
    d. Walk around the structure, taking note at any irregularities.
        i. Take thermal and regular photos of the exterior.
    e. Check for control system or time clocks used to control equipment and lights.
5. Develop exit questions for the owner/representative/contact person.
    a. Ask about anything that was unclear.
    b. Ask about any equipment that was not found.
    c. Make sure to answer their questions, if any.

Post-Audit

1. Add all data to the audit documents.
2. Title and save all photos for documentation and later clarification.

Instructions for Audit and How to Use the Audit Workbook

There are many sections within the audit workbook. This how-to guide will step-through each section and what information should be gathered.

1. Building Information
    a. Name of building
    b. Address of building
    c. Date and weather conditions at time of audit
    d. Introduce yourself to building manager, and take down their name and number.
    e. Make note of the auditing team.
    f. Next, describe the building type in general and building function.
    g. Ask owner/operator if previous audits have been performed.
    h. Ask owner/operator if energy saving measures are currently being implemented or if there are plans for some to be initiated.
    i. Ask owner/operator for typical occupied hours are for the building.
    j. Ask owner/operator for typical thermostat set points (or get the information from the room data).
    k. Lastly, ask the owner/operator for average number of occupants.
2. Room Sheet
    a. For each room, fill out one of these sheets.
    b. Room Name
    c. Room Number (If available)
    d. Thermostat? If yes, what is the temperature set at?
    e. Note temperature and relative humidity in the space
    f. Lighting
        i. First, describe the fixture with number of lamps (i.e. 2’x4’ lay-in with (2) T8 lamps).

    ii. Note whether the ballast is magnetic or electronic. Either use a “ballast checker” or use the general rule that T12s usually have magnetic ballasts and T8/T5s usually have electronic ballasts.
    iii. Then, take the footcandle reading. Stand in the center of the room. Take the measurement with a lightmeter at 36” above the floor (common working-plane height).
    iv. Lastly, note the controls for the lights (occupancy sensors, manual toggles, etc.).

g. Equipment
    i. Take inventory of all equipment that requires power (i.e. exhaust fan, computer, etc.).
    ii. If there is an exhaust fan, is it tied to the light or does it have independent control?

h. Exterior Doors
    i. Are there exterior doors in the space?
        1. Note the quantity, type (metal, wood, orientation), size and condition.
            a. Door Conditions can be defined as—
                i. Good: Door has no obvious defects and no visible gaps when shut.
                ii. Fair: Door has minor defects (dents, scratches, cracks) that do not affect operation or allow gaps.
                iii. Poor: Door has major defects (dents, scratches, cracks) that prevent proper operation and results in gaps to outside.

i. Exterior Windows
    i. Are there exterior windows in the space?
        1. Note the quantity, type (operable, number of panes, shading, orientation), size and condition

            a. Window conditions can be defined as—
                i. Good: Window has no obvious defects, no visible gaps when shut and glazing is intact.
                ii. Fair: Window has minor defects (scratches, cracks) that do not affect operation or allow gaps; minor cracks in glazing.
                iii. Poor: Window has major defects (scratches, cracks) that prevent proper operation and results in gaps to outside; extensive cracks in glazing.

3. Building Characteristics
    a. Most of the information will need to be taken from a floor plan or consolidated from the individual room sheets.
    b. Note the floor area of the building.
        i. What percent of the area is conditioned?
    c. Compile the total door areas and conditions.
    d. Compile the total glass areas and conditions.
    e. Note the construction of the walls and roof.
        i. If available from the plans or inspection, note the insulation.
    f. Note how the building is metered for utilities.
4. HVAC Distribution System
    a. First, note the location of the equipment.
    b. There are multiple sections on this sheet in case there are multiple systems within the building, but each section requires the same information.
    c. First, system type
        i. Check box the type of the system.
        ii. Note the maintenance of the items
        iii. Record a detailed description of the system, such as brand, model number, etc.; use the boxes on the right.

        iv. Then, if ductwork is used to transmit conditioned air, note the condition of the insulation and installation.
        v. Lastly, check box the type of control scheme used with the system.

5. Domestic Hot Water
    a. First, check box the type of fuel used to heat the water.
    b. Next, in the box to the right, describe the water heater installed.
        i. Include brand, model, gallon capacity, BTUh input, and any other information provided on the unit.
    c. Note the number of units, location of units, and if there is a recirculation loop attached to the water heater.
    d. Next, note the temperature at the heater, both entering (city water) and leaving (at heater).
    e. Hot water temperature “at point of use” is measured at the individual lavatory faucets. The temperature “at point of use” should not be more than 110 degrees Fahrenheit.
    f. If available, record the water heater’s manufacturer and installation date.
    g. Next, answer the check box questions regarding the heater’s condition.
    h. The last item is to note if hot water is used for just the public lavatories, or for other building uses as well.
6. Water Consumption
    a. Tally the number of water-using fixtures within the building.
    b. Note the gallons/flush or gallons/minute of flow for the fixtures.
    c. Next, record the hot and cold water temperatures “at point of use” in the public restrooms.
    d. Lastly, ask the owner/operator if there are any periods throughout the year when large amounts of water are used (i.e. Irrigation, Filling Tanks, etc.).
7. Specialty Equipment

    a. Note all the power-drawing equipment within the building. The simplest way to achieve this is to record the equipment on a room-by-room basis and compile the sheets after the audit is complete.

8. Lighting
    a. For the interior and exterior of the building, compile the lighting utilized throughout. The simplest way to achieve this is to record the lighting information on a room-by-room basis and compile the sheets after the audit is complete.

After the Audit

After completing the audit, thank the owner/operator who assisted with the audit process and make sure to take their contact information in case questions arise after you have left the audit site.

Example after-audit questions:

1. Are the occupants content/happy with the temperatures?
2. Lighting – Is there a preference as to what lights should be on/off?
3. If the water temperature is high, is it required for a certain process?

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On-Site Energy Audit Worksheets

Building Information

Name of Institution, Building	Building # --
Address (Street or P.O. Box)	City, State, Zip

Date of Audit	Time of Audit	Weather Conditions

Building Manager	Building Manager's Phone Number
Auditing Team	Phone

Building Type and Use

Building Use	% Dedicated to this Use
☐ Office	________
☐ Storage	________
☐ Maintenance Garage	________
☐ Other - Shop	________

Building Description / Type:

Date of Construction: ________

Original Architects, if known	Original Engineers, if known

Does the Institution have an ongoing Energy Management Program? ☐ Yes ☐ No

If yes, describe program: ________________________

Any previous energy audits completed? ☐ Yes ☐ No Dates:

Name of Utilities: Electric, Gas, etc.

Building Information

List of Energy Savings Programs or Efforts Currently Implemented:

No. Years Implemented

1.______________________________
2.______________________________
3.______________________________
4.______________________________
5.______________________________

Conservation Measures Under Consideration Prior to this Audit.

1.______________________________
2.______________________________
3.______________________________
4.______________________________

What are the facility manager's feelings towards saving energy?

Priority of Saving Energy and Money with Utilit Low 1 2 3 4 5 6 7 8 9 10

What are the barriers to implementing energy saving strategies?

☐ Lack of Information
☐ Lack of Funds
☐ Lack of Support from Upper Management
☐ Other :

Building Information

Building Occupancy Profile

Typical Occupied Periods:

Hours (i.e. 8am - 5pm)

Sunday ____________________
Monday ____________________
Tuesday ____________________
Wednesday ____________________
Thursday ____________________
Friday ____________________
Saturday ____________________

Thermostat Set points: Daytime Heating __________ Cooling __________
Nighttime Heating __________ Cooling __________
Weekend Heating __________ Cooling __________

Average Number of Occupants in Building: __________

Include a Floor Plan.

1. Look for discrepancies between plan and existing conditions.
2. Mark locations of heating and cooling units.

Definitions:

General

Good: In regards to an item being satisfactory in quality, quantity, or degree

Fair: In regards to an item being neither good nor poor; moderate or tolerable

Poor: In regards to an item being deficient or lacking in something specified

Doors

Good: Door has no obvious defects (dents, scratches, cracks) and no visible gaps when shut

Fair: Door has minor defects (dents, scratches, cracks) that do not affect operation or allows gaps

Poor: Door has major defects (dents, scratches, cracks) that prevent proper operation and results in gaps to outside.

Windows

Good: Window has no obvious defects (scratches, cracks), no visible gaps when shut, glazing is intact

Fair: Window has minor defects (scratches, cracks) that do not affect operation or allow gaps, minor cracks in glazing

Poor: Window has major defects (scratches, cracks) that prevent proper operation and results in gaps to outside, extensive cracks in glazing

ROOM NAME: ____________________

ROOM NUMBER: __________

Thermostat? ☐ Yes ☐ No Setting: __________ ° F

Temperature __________ ° F
Relative Humidity __________ %

Lighting:	Ballast	Footcandles	Controls

All Lights On: __________

Equipment:

		Quantity
Exhaust Fan	☐ Yes ☐ No	
Computer	☐ Yes ☐ No	

Exterior Doors: ☐ Yes ☐ No

Standard Doors: Quantity: __________
Type: __________
Size: __________

Door Condition:
☐ Good
☐ Fair
☐ Poor

Shop Doors: Quantity: __________
Type: __________
Size: __________

Door Condition:
☐ Good
☐ Fair
☐ Poor

Exterior Windows: ☐ Yes ☐ No

Windows: Quantity: __________
Type: __________
Size: __________

Window Condition:
☐ Good
☐ Fair
☐ Poor

Windows: Quantity: __________
Type: __________
Size: __________

Window Condition:
☐ Good
☐ Fair
☐ Poor

Building Characteristics

Gross Floor Area ____ gross sf , ceiling ht ____ ft
____ gross sf , ceiling ht ____ ft
____ gross sf , ceiling ht ____ ft
* If multiple ceiling heights

Conditioned Floor Area Heating Only: ____ sf
Cooling Only: ____ sf
Heating and Cooling: ____ sf

Number of Conditioned Floors:
Above Grade ____
Below Grade ____

Total Standard Door Area ____ sf Glass ____ sf Door Condition:
Wood ____ sf ☐ Good
Metal ____ sf ☐ Fair
Garage ____ sf ☐ Poor

Total Shop Door Area ____ sf Glass ____ sf Door Condition:
Wood ____ sf ☐ Good
Metal ____ sf ☐ Fair
Garage ____ sf ☐ Poor

Office Exterior Glass Area ____ sf Single Panes ____ sf Window Condition:
(Note: Operable or Fixed) Double Panes ____ sf ☐ Good
☐ Fair
North Total Area ____ sf ☐ Poor
Single Panes ____ sf
Double Panes ____ sf

South Total Area ____ sf
Single Panes ____ sf
Double Panes ____ sf

East Total Area ____ sf
Single Panes ____ sf
Double Panes ____ sf

West Total Area ____ sf
Single Panes ____ sf
Double Panes ____ sf

Shop Ext Glass Area ________ sf
(Note: Operable or Fixed)

Single Panes ________ sf
Double Panes ________ sf

Window Condition:
☐ Good
☐ Fair
☐ Poor

North
Total Area ________ sf
Single Panes ________ sf
Double Panes ________ sf

South
Total Area ________ sf
Single Panes ________ sf
Double Panes ________ sf

East
Total Area ________ sf
Single Panes ________ sf
Double Panes ________ sf

West
Total Area ________ sf
Single Panes ________ sf
Double Panes sf

Office Exterior Wall Are________ sf
☐ Masonry
☐ Wood
☐ Concrete
☐ Stucco
☐ Other
☐ Unknown

Shop Ext Wall Area ________ sf
☐ Masonry
☐ Wood
☐ Concrete
☐ Stucco
☐ Other
☐ Unknown

Total Roof Area ________ sf
Condition:
☐ Good
☐ Fair
☐ Poor

Insulation Type Roof: ____________________

Wall: ____________________

Floor: ____________________

Insulation Thick Roof: ____________________

Wall: ____________________

Floor: ____________________

If Provided on Building Plans.

Metering:

Is this building individually metered for electricity? ☐ Yes ☐ No

Is this building individually metered for natural gas / LP? ☐ Yes ☐ No

Is this building individually metered for water? ☐ Yes ☐ No

Describe the general building condition:

HEATING PLANT

PRIMARY

SYSTEM TYPE	Quantity	Rated Input	Rated Output
☐ Fire Tube-Steam			
☐ Water Tube-Steam			
☐ Fire Tube-Hot Water			
☐ Water Tube-Hot Water			
☐ Electric Resistance			
☐ Heat Pump, Aux. Elec Heat			
☐ Purchased Steam			
☐ Other			

ENERGY SOURCE	MAINTENANCE	CONTROLS
☐ Natural Gas	☐ Good	☐ Manual
☐ LP Gas	☐ Fair	☐ Somewhat Automated
☐ #2 Fuel Oil	☐ Poor	☐ Highly Automated
☐ #4 Fuel Oil		
☐ #6 Fuel Oil		
☐ Electricity		
☐ Coal		
☐ Wood		
☐ Solar		
☐ Puchased Steam		

SECONDARY

SYSTEM TYPE	Quantity	Rated Input	Rated Output
☐ Fire Tube-Steam			
☐ Water Tube-Steam			
☐ Fire Tube-Hot Water			
☐ Water Tube-Hot Water			
☐ Electric Resistance			
☐ Heat Pump, Aux. Elec Heat			
☐ Purchased Steam			
☐ Other			

ENERGY SOURCE	MAINTENANCE	CONTROLS
☐ Natural Gas	☐ Good	☐ Manual
☐ LP Gas	☐ Fair	☐ Somewhat Automated
☐ #2 Fuel Oil	☐ Poor	☐ Highly Automated
☐ #4 Fuel Oil		
☐ #6 Fuel Oil		
☐ Electricity		
☐ Coal		
☐ Wood		
☐ Solar		
☐ Puchased Steam		

Potential for Waste Heat Recovery?

☐ Yes ☐ No

SECONDARY #2

SYSTEM TYPE	Quantity	Rated Input	Rated Output
☐ Fire Tube-Steam			
☐ Water Tube-Steam			
☐ Fire Tube-Hot Water			
☐ Water Tube-Hot Water			
☐ Electric Resistance			
☐ Heat Pump, Aux. Elec Heat			
☐ Purchased Steam			
☐ Other ______________			

ENERGY SOURCE

- ☐ Natural Gas
- ☐ LP Gas
- ☐ #2 Fuel Oil
- ☐ #4 Fuel Oil
- ☐ #6 Fuel Oil
- ☐ Electricity
- ☐ Coal
- ☐ Wood
- ☐ Solar
- ☐ Puchased Steam

MAINTENANCE

- ☐ Good
- ☐ Fair
- ☐ Poor

CONTROLS

- ☐ Manual
- ☐ Somewhat Automated
- ☐ Highly Automated

Potential for Waste Heat Recovery?

☐ Yes ☐ No

OPERATION PROFILE

__________ hrs/weekday

__________ hrs/Saturday

__________ hrs/Sunday

__________ wks/yr

Estimated Annual Hours of Operation: __________

From (month) __________ through __________

Thermostat Set Points

Day: __________

Night: __________

Weekends: __________

COOLING PLANT

PRIMARY

SYSTEM TYPE

- ☐ Reciprocating Chiller
- ☐ Centrifugal Chiller
- ☐ Absorption Chiller
- ☐ Solar Assisted-Absorption Chiller
- ☐ Evaporative Chiller
- ☐ Heat Pump
- ☐ DX System
- ☐ Screw Compressor
- ☐ Window or Thru-Wall Unit
- ☐ Other ____________

ENERGY SOURCE

- ☐ Electric Motor
- ☐ Combustion Engine
- ☐ Steam Turbine
- ☐ Steam Boiler
- ☐ Purchased Steam
- ☐ Other ____________

MAINTENANCE

- ☐ Good
- ☐ Fair
- ☐ Poor

CONTROLS

- ☐ Manual
- ☐ Somewhat Automated
- ☐ Highly Automated

VOLTAGE

- ☐ 120 / Single Phase
- ☐ 208-120 / Single Phase
- ☐ 208-220 / 3 Phase
- ☐ 440-480 / 3 Phase

OPERATION PROFILE

________ hrs/weekday

________ hrs/Saturday

________ hrs/Sunday

________ wks/yr

Estimated Annual Hours of Operation: ________

From (month) ________ through ________

Thermostat Set Points

Day: ________

Night: ________

Weekends: ________

HVAC DISTRIBUTION SYSTEM

Location of Unit(s)

SYSTEM 1

SYSTEM TYPE

- ☐ Single Zone (Furnace, RTU, etc.)
- ☐ Multi Zone (i.e. AHU)
- ☐ Dual Duct
- ☐ Variable Air Volume
- ☐ Single Duct Reheat
- ☐ 2-Pipe Water
- ☐ 4-Pipe Water
- ☐ Window Unit
- ☐ Packaged Air Terminal Unit
- ☐ Unit Ventilator
- ☐ Fan Coil
- ☐ Unit Heater
- ☐ Other ____________

MAINTENANCE

- ☐ Good
- ☐ Fair
- ☐ Poor

DUCTWORK Insulation:

- ☐ Good
- ☐ Fair
- ☐ Poor

Installation:

- ☐ Good
- ☐ Fair
- ☐ Poor

CONTROLS

- ☐ Space Thermostat
- ☐ Outside Temperature Sensors
- ☐ Time Clocks
- ☐ Energy Management System
- ☐ Auto Supply Temperature Reset
- ☐ Economy Cycle
- ☐ Heat Recovery
- ☐ Other ____________

Style:

SYSTEM 2

SYSTEM TYPE

☐ Single Zone
☐ Multi Zone
☐ Dual Duct
☐ Variable Air Volume
☐ Single Duct Reheat
☐ 2-Pipe Water
☐ 4-Pipe Water
☐ Window Unit
☐ Unit Ventilator
☐ Fan Coil
☐ Unit Heater
☐ Other ____________

MAINTENANCE

☐ Good
☐ Fair
☐ Poor

CONTROLS

☐ Space Thermostat
☐ Outside Temperature Sensors
☐ Time Clocks
☐ Energy Management System
☐ Auto Supply Temperature Reset
☐ Economy Cycle
☐ Heat Recovery
☐ Other ____________

SYSTEM 3

SYSTEM TYPE

- ☐ Single Zone
- ☐ Multi Zone
- ☐ Dual Duct
- ☐ Variable Air Volume
- ☐ Single Duct Reheat
- ☐ 2-Pipe Water
- ☐ 4-Pipe Water
- ☐ Window Unit
- ☐ Unit Ventilator
- ☐ Fan Coil
- ☐ Unit Heater
- ☐ Other ____________

MAINTENANCE

- ☐ Good
- ☐ Fair
- ☐ Poor

CONTROLS

- ☐ Space Thermostat
- ☐ Outside Temperature Sensors
- ☐ Time Clocks
- ☐ Energy Management System
- ☐ Auto Supply Temperature Reset
- ☐ Economy Cycle
- ☐ Heat Recovery
- ☐ Other ____________

DOMESTIC HOT WATER

Domestic Hot Water Heated By:

☐ Electricity
☐ Natural Gas
☐ Oil
☐ Steam
☐ Heat Pump
☐ Other ____________

Number of Units: ____________

General Location of Units: ____________

Is there a re-circulation loop? ☐ Yes ☐ No

Hot Water Temperature

At Point of Use ____________

At Heater ____________

Temperature of City Water ____________

Date of Water Heater ____________

Date of Installation ____________

Is the tank warm to the touch? ☐ Yes ☐ No

Are pipes insulated at least 3' from heater? ☐ Yes ☐ No

Any signs of leakage? ☐ Yes ☐ No

Requires maintenance? ☐ Yes ☐ No

Is the tank wrapped? ☐ Yes ☐ No

Do obstructions prevent wrapping? ☐ Yes ☐ No

Distance from Heater to Furthest Point of Use: ____________

Hot Water Uses Other than Lavatories:

WATER CONSUMPTION

Fixture Type	Quantity	Gal/Flush	Gal/Min	Low-Flow?	Aerators?
Water Closets (tank)					
Water Closets (valve)					
Urinals					
Lavatories					
Service Sinks					
Showers					
Electric Water Coolers					
Dishwashers					
Hose Bibs					

Exhaust Fans tied to Lights? ☐ Yes ☐ No

HW Temperature = °F

CW Temperature = °F

Large Water Consumption Scenarios

	Yes	No	Time Period of Water Usage	Estimated Amount
Irrigation - Sprinkler System				
Filling Water Tanks				
Other: ______________				

SPECIALTY EQUIPMENT

Item	Yes / No	Quantity
Refrigerators		
Mini-Fridges		
Freezers		
Walk-In Refrigerators		
Walk-In Freezers		
Microwaves		
Mixers		
Ranges		
Ovens		
Dishwashers		
Hoods w/ Exhaust Fans		
Coffee Makers		
Pop Machines		
Vending Machines		
Ice Makers		
Space Heaters		
Copiers		
Fax Machines		
Scanners		
Printers		
Printer/Fax/Scan/Copy Machines		
Plotters		
Compressors		
Motors		
Presses		
Laser Cutting Machine - Independent Exhaust Fan		
Press Brake Machine		
Waterjet Cutting Machine		
CNC Lathe		
CNC Mill		
Powder Paint Curing Oven		
Misc. Manual Shop Lathes/Mills		
Welding Machines		
Test Fixtures		
Exhaust Fans (Separate from Light)		
Computers		
Projector / Screen		

Lighting

INTERIOR

Building Area	Fixture Type	# of Fixtures	Watts per Fixture	Avg Footcandles	Ballast

EXTERIOR

Building Area	Fixture Type	# of Fixtures	Watts per Fixture	Avg Footcandles	Ballast

Fixture Types:

Incandescent
Fluorescent
Mercury Vapor
High Pressure Sodium
Low Pressure Sodium
Metal Halide

Are lights on in unoccupied areas? ☐ Yes ☐ No
Is the exterior lighting on during the day? ☐ Yes ☐ No

How are lights operated?
☐ Toggle Switches
☐ Occupancy Switches
☐ Photovoltaic/Daylight Sensors
☐ Other ____________

Tool Guide with Photos

- Flashlight: Use to examine dark spaces.

Figure B-1 Flashlight

- Camera: Take photos to document current conditions and equipment.

Figure B-2 Digital Camera

- Yardstick: Use to make sure that all temperature and light level readings are taken at the same height.

Figure B-3 Yardstick

- Thermal Camera: Use to take photos of the building to identify any areas where heat is lost/gained through the envelope. Can also be used to determine if insulation is effective. If a thermal camera is unavailable, visually check for sealing around joints and feel for intruding air.

Figure B-4 Thermal Camera

- 4-in-1 device(s): Use to measure light levels at working plane (typically 3’ above floor) and the temperature and relative humidity in each space. Use with the probe to measure the temperature of cold and hot water at plumbing fixtures. If a 4-in-1 device is unavailable, use a lightometer, thermometer, and hygrometer separately to note the light level, temperature, and relative humidity.

Figure B-5 4-in-1 Device

- Highlighters: Use to highlight the plans if any discrepancies are identified and to highlight any issues on the worksheets.

Figure B-6 Highlighter

- Plans: Use the plans to make sure all spaces are accounted for and are accurate according to the plans.

Figure B-7 Building Plans

- Clipboards: Use clipboards to keep all sheets organized and provide a surface to write on.

Figure B-8 Clipboard

- Pens & Pencils: Use to document everything and fill out the audit worksheets.

Figure B-9 Pens and Pencils

Appendix C - Audit Results Checklist

Within this appendix, an audit results checklist is provided. The checklist is organized in categories of: lighting and power, building envelope, HVAC, plumbing, and building occupancy. The purpose of the results checklist is to allow for a simpler compilation of recommendations for a certain building based on the energy audit results. To use the checklist efficiently, the checklist first provides a problem statement. If the statement is true, look at the subsection recommendations listed below it. Some items will be applicable and others will not, but the list of recommendations is meant to be universal for all building scenarios. If the problem statement does not apply to the building, then check "no" and move onto the next item.

LIGHTING		Problem?		Recommended?	
		Yes	No	Yes	No
1. Incandescent lamps are used in office, workrooms, hallways, and gymnasiums.		☐	☐		
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.			☐	☐
d.	Replace non-decorative incandescent lamps with more energy conserving types such as fluorescents in general purpose areas and HIDs in large group areas.			☐	☐
2. Lamps and fixtures are not clean.		☐	☐		
a.	Establish a regular inspection and cleaning schedule for lamps and 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 fixtures with modern type fixtures that are easy to clean.			☐	☐
3. Lamps are replaced individually as they burn out.		☐	☐		
a.	Establish a group relamping schedule. Lamp manufacturer's sales offices can provide a computerized relamping schedule at minimal to no cost.			☐	☐
4. Ceilings and other room surfaces have reduced reflectivity due to dirt.		☐	☐		
a.	Clean surfaces.			☐	☐
b.	When repainting or recovering, use coatings or coverings with good reflectance.			☐	☐
5. Daylighting is not used effectively.		☐	☐		
a.	Locate work stations requiring high illumination adjacent to windows.			☐	☐
b.	Switch off lights when daylight is sufficient.			☐	☐
c.	Clean windows and skylights.			☐	☐
d.	Install light sensors and dimming equipment which automatically compensate for varying natural lighting conditions.			☐	☐

LIGHTING		Problem?		Recommended?	
		Yes	No	Yes	No
6. Decorative lighting is excessive and/or not controlled optimally.		☐	☐		
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.			☐	☐
7. In fixtures where fluorescent lamps have been removed, the ballasts have not been disconnected.		☐	☐		
a.	Disconnect ballasts.			☐	☐
8. Lighting is on in unoccupied areas.		☐	☐		
a.	Post instructions to turn off lights when leaving area.			☐	☐
b.	Identify areas being controlled by gang switches.			☐	☐
c.	Assure wall switch timers function properly.			☐	☐
d.	Provide timer switches/occupancy switches in remote ot seldom used areas where there will be brief occupancy periods.			☐	☐
9. Security/outdoor lighting is not automatically controlled and/or lighting levels are excessive.		☐	☐		
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.			☐	☐
e.	Replace exterior incandescent lamps with more efficient types such as High Pressure Sodium or Metal Halide.			☐	☐
10. Deep baffled downlighting fixtures have conventional "R" reflector lamps installed.		☐	☐		
a.	Replace burned out "R" lamps with elliptical reflector "ER" lamps which yield approximately the same average light level for half the energy cost.			☐	☐
11. Two lamps have not been removed from four-lamp fixtures where possible.		☐	☐		
a.	Remove two lamps and disconnect ballasts.			☐	☐

POWER		Problem?		Recommended?	
		Yes	No	Yes	No
1. Transformers remain energized when serving no load for extended periods.		☐	☐		
a.	Disconnect transformer.			☐	☐
2. Transformer ambient temperature is high.		☐	☐		
a.	Assure that a forced ventilation system serving the space is functioning or that a natural ventilation system's openings are not			☐	☐
3. Vending machines remain energized during unoccupied periods.		☐	☐		
a.	Provide manual operation schedule or connect to existing time clocks or programmable controllers.			☐	☐
4. Refrigerator drinking fountains or recirculating chilled drinking water systems are not controlled for occupancy.		☐	☐		
a.	Provide manual operation schedule or connect to existing time clocks or programmable controllers.			☐	☐
5. Elevator operation is not optimized for occupancy variations.		☐	☐		
a.	Consult with manufacturer for possible operating changes.			☐	☐
6. Lubricants used on major rotating equipment with high load factors have not been optimized for reduction of friction losses.		☐	☐		
a.	Consult with equipment manufacturers and lubricant manufacturers to determine if lubricant change is cost-effective.			☐	☐
7. Substantial electricity demand charges are incurred.		☐	☐		
a.	Determine is use of major electrical equipment can be scheduled to reduce demand.			☐	☐

	BUILDING ENVELOPE	Problem?		Recommended?	
		Yes	No	Yes	No
	1. Improper alignment/operation of windows and doors allows excessive infiltration.	☐	☐		
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 on all doors.			☐	☐
d.	Resize exterior doors. (Make delivery doors smaller to reduce infiltration)			☐	☐
e.	Add expandable separate enclosures, where practical.			☐	☐
f.	Install self-closing doors on openings to unconditioned spaces.			☐	☐
g.	Install a switch on overhead doors that prevent activation of heating and cooling units when doors are open.			☐	☐
h.	Install vestibule doors at major entrances.			☐	☐
	2. Weather-stripping and/or caulking around all areas of infiltration is worn, broken or missing.	☐	☐		
a.	Replace worn and/or broken weather stripping and caulking.			☐	☐
b.	Replace broken or cracked windows.			☐	☐
	3. Doors and/or windows separating conditioned from non-conditioned areas are left open.	☐	☐		
a.	Assure that automatic door closers function properly.			☐	☐
	4. Excessive expanses of glass exist on exterior walls.	☐	☐		
a.	When replacing windows, replace with thermopanes, utilizing the same casings.			☐	☐
b.	Keep curtains and drapes closed in unoccupied spaces.			☐	☐
c.	Totally or partially insulate non-operable windows.			☐	☐
d.	Consider adding reflective or heat absorbing film to minimize solar gain.			☐	☐
e.	Install double-pane windows.			☐	☐
f.	Install adjustable outdoor shading devices.			☐	☐
g.	Attach storm glazing to moveable sash of operable windows.			☐	☐

BUILDING ENVELOPE		Problem?		Recommended?	
		Yes	No	Yes	No
5. There is no insulation between conditioned and unconditioned spaces.		☐	☐		
a.	Insulate between heated/cooled spaces and unconditioned or outside areas.			☐	☐
6. Ceiling/roof insulation is inadequate or has been water damaged.		☐	☐		
a.	Before replacing water damaged insulation, repair roof where required.			☐	☐
b.	Verify that vapor barrier faces the conditioned space and is intact.			☐	☐
c.	Add new insulation to meet recommended standard.			☐	☐
7. Blinds and Curtains are not used to help insulate the building.		☐	☐		
a.	Instruct personnel to close interior shading devices.			☐	☐
b.	Repair or replace damaged/missing shading devices.			☐	☐
c.	Add reflective or absorbing films to reduce solar gains.			☐	☐
d.	Install outdoor shading devices.			☐	☐

HVAC		Problem?		Recommended?	
		Yes	No	Yes	No
1. Air filters and heating/cooling coils do not receive scheduled maintenance.		☐	☐		
a.	Develop maintenance schedule.			☐	☐
b.	Install filter pressure-drop gauges.			☐	☐
2. Duct or pipe insulation is damaged or missing.		☐	☐		
a.	Repair.			☐	☐
b.	Replace.			☐	☐
c.	Protect.			☐	☐
3. Fan drive belts deflect excessively.		☐	☐		
a.	Adjust fan belt tension.			☐	☐
4. Air leaks from ducts and plenums are noticeable.		☐	☐		
a.	Repair leaks.			☐	☐
5. Air inlets and outlets are dirty or obstructed.		☐	☐		
a.	Clean			☐	☐
b.	Remove obstruction			☐	☐
c.	Remove access covers and inspect turning vanes, fire dampers, and splitters.			☐	☐
6. Boiler combustion effiency is not tested on a scheduled basis.		☐	☐		
a.	Prepare testing schedule and log of test results.			☐	☐
b.	Conduct combustion effiency test.			☐	☐
7. Boilers are not maintained on a scheduled basis.		☐	☐		
a.	Perform maintenance per manufacturer's instructions.			☐	☐

HVAC		Problem?		Recommended?	
		Yes	No	Yes	No
8. Multiple boilers or heaters fire simultaneously.		☐	☐		
a.	Adjust controls so that boiler #2 will not fire until boiler #1 can no longer satisfy the demand.			☐	☐
b.	Purchase and install automatic staging controls, if applicable.			☐	☐
9. Stack temperature appears excessively high (greater than 400°F plus room temperature).		☐	☐		
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.			☐	☐
e.	Purchase a kit for flue gas analysis if frequent testing is anticipated.			☐	☐

HVAC - CONTROLS		Problem?		Recommended?	
		Yes	No	Yes	No
1. Thermostats on heating/cooling units are vulnerable to occupant adjustment.		☐	☐		
a.	Reset thermostats to correct settings.			☐	☐
b.	Install or replace locking screws to prevent tampering.			☐	☐
c.	Install tamper-proof locking covers on thermostats.			☐	☐
2. Space temperatures are higher or lower than thermostat settings.		☐	☐		
a.	Recalibrate thermostat.			☐	☐
b.	Blow out moisture, oil and dirt form pneumatic lines; clean contacts if electrical control system.			☐	☐
c.	Recalibrate controllers.			☐	☐
d.	Ensure that control valves and dampers are modulated properly.			☐	☐
e.	Make sure that air intake volume is not excessive.			☐	☐
3. Thermostat settings have not been adjusted for change in seasons.		☐	☐		
a.	Adjust thermostats to 68°F in heating season, and 78°F during cooling season.			☐	☐
b.	Change the location of thermostats from areas subject to extreme temperature flucuations, such as next to window, or over a heating or cooling unit.			☐	☐
4. Control devices are not inspected on a regular basis.		☐	☐		
a.	Routinely check all time clocks and other control equipment for proper operation.			☐	☐
5. Building temperatures are not adjusted for unoccupied periods.		☐	☐		
a.	Reduce thermostat settings by a minimum of 10°F at nights, weekends and holidays during heating season.			☐	☐
b.	Shut down air conditioning units at night, on weekends, holidays.			☐	☐
c.	Install automatic controls such as time clocks or an automated management system.			☐	☐
6. Unoccupied or little used areas are heated or cooled unnecessarily.		☐	☐		
a.	Reduce winter thermostat settings to 55°F in unoccupied areas.			☐	☐
b.	Increase summer thermostat setting, if possible.			☐	☐

	HVAC - HEATING	Problem?		Recommended?	
		Yes	No	Yes	No
1. Water in heating system is heated when there is no need.		☐	☐		
a.	Turn off boiler, pumps or heat source.			☐	☐
b.	Install control to automatically shut down heat generating device when outside air temperature reaches 60°F.			☐	☐
2. Condensate from street stream is being discharged to sewer drain.		☐	☐		
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.			☐	☐
3. Heating pilot lights are on during the cooling season.		☐	☐		
a.	Turn pilots off.			☐	☐
b.	Replace worn units with new electronic ignition models to avoid unnecessary fuel consumption.			☐	☐
4. Steam radiators or other steam equipment fails to heat, or is operating erratically.		☐	☐		
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. Initiate a stream 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.			☐	☐
5. Steam, condensate and heating water piping insulation is in disrepair or missing.		☐	☐		
a.	Inspect pipes for broken or missing insulation. Repair or replace as needed.			☐	☐
b.	Install additional pipe insulation in accordance with design specifications and energy conservation codes.			☐	☐

HVAC - HEATING		Problem?		Recommended?	
		Yes	No	Yes	No
6. Operation of oil burner is accompanied by excessive smoke and sooting.		☐	☐		
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.			☐	☐
f.	Pressure kit for flue gas analysis if frequent testing is anticipated.			☐	☐
g.	Purchase new burner nozzles or tips.			☐	☐
7. Soot and odors are detected in areas where they are not exposed.		☐	☐		
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 ratio.			☐	☐
d.	Check operation of furnace draft controller.			☐	☐
e.	Check boiler setting for leaks.			☐	☐
8. Evidence indicated faulty or inefficient boilers or furnaces.		☐	☐		
a.	Remove scale deposits, accumulation of sediment and boiler compounds on water side surfaces.			☐	☐
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.			☐	☐
d.	Inspect all boiler insulation, refractory, brick work and boiler casing for hot spots and air leaks. Repair and seal as necessary.			☐	☐
e.	Replace dangerous or ineffective units with more efficient modular type units.			☐	☐
9. Air is humidified.		☐	☐		
a.	Discontinue or reduce humidification where possible.			☐	☐

HVAC - HEATING		Problem?		Recommended?	
		Yes	No	Yes	No
10. Burner short-cycles.		☐	☐		
a.	Start-stop limit switches may be set too closely. Reset as required.			☐	☐
b.	Thermostat may be faulty.			☐	☐
c.	Employ control specialist to adjust control.			☐	☐
11. Combustion air to boiler/furnace is not preheated.		☐	☐		
a.	Utilize heat from flue gas to preheat combustion air by means of a heat recovery device.			☐	☐
b.	Consider economizer to transfer heat from flue gas to feed water.			☐	☐
c.	Consider heat recovery from continuous blowdown.			☐	☐
12. Hot wate radiation units fail to operate.		☐	☐		
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. 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.			☐	☐
13. Radiators, convectors, baseboards and finned-tube heaters are not providing sufficient heat.		☐	☐		
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. 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.			☐	☐

HVAC - HEATING		Problem?		Recommended?	
		Yes	No	Yes	No
14. Condensors and cooling towers are not maintained on a scheduled basis.		☐	☐		
a.	Prepare maintenance schedule. Perform maintenance per manufacturer's recommendations.			☐	☐
b.	Maintain cooling tower water.			☐	☐
15. Circulating pump operation is manually controlled.		☐	☐		
a.	Develop operating schedule.			☐	☐

HVAC - COOLING		Problem?		Recommended?	
		Yes	No	Yes	No
1. Multiple air conditioning compressors start simulatneously.		☐	☐		
a.	Adjust controls to stage compressors.			☐	☐
b.	Should automatic controls not exist, puchase and install. This will allow compressor #2 to cut in when compressor #1 can no longer satisfy space conditioning load.			☐	☐
2. Chiller evaporating and condensing temperatures are not optimized.		☐	☐		
a.	Increase chiller evaporator temperature following manufacturer's recommendations.			☐	☐
b.	Decrease chiller condensing temperature following manufacturer's recommendations.			☐	☐
3. Reheat coils are used to maintain zone temperatures.		☐	☐		
a.	Convert to variable air volume system if the reheat coils are not necessary to supply heat during the heating season.			☐	☐
4. Building utilizes a dual duct or multizone system.		☐	☐		
a.	Convert dual duct or multizone systems to variable air volume, if buildign has a separate heating season.			☐	☐
b.	Install controls to automatically reset hot and cold deck temperatures.			☐	☐
5. Air conditioning load trips circuit breaker on extremely warm days.		☐	☐		
a.	Tighten wire lugs if loose.			☐	☐
b.	Replace defective circuit breakers.			☐	☐
c.	Clean condensor on air cooled systems.			☐	☐
d.	Clean scale build-up in condensor on water cooled systems.			☐	☐

HVAC - COOLING		Problem?		Recommended?	
		Yes	No	Yes	No
6. Air of inadequate volume or temperature is being discharged through grilles.		☐	☐		
a.	Defrost evaporative coil if iced. Determine cause if 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 condensor coil and/or water tower nozzles.			☐	☐
h.	Install differential pressure-sensing switches to alarm when air flow drops significantly.			☐	☐
7. Refrigeration condensors or coils are dirty, clogged and/or not functioning efficiently.		☐	☐		
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 condensors which will decrease system efficiency. High discharge temperatures are often caused by defective or broken compressor valves. Repair or adjust as required.			☐	☐
c.	Inspect the liquid line leaving the strainer. If it feels cooler that 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.			☐	☐
8. Chilled water piping, valves and fittings are leaking.		☐	☐		
a.	Repair joint or piping leaks.			☐	☐
b.	Repair or replace valves.			☐	☐
9. Chiller operation is not optimized (Listen for short-cycling).		☐	☐		
a.	Raise chilled water supply temperature.			☐	☐
b.	Remove scale deposits from condensors.			☐	☐
c.	Check refrigerant charge.			☐	☐

HVAC - COOLING		Problem?		Recommended?	
		Yes	No	Yes	No
10. Refrigeration compressor short-cycles.		☐	☐		
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.			☐	☐
f.	If frost is detected on the liquid line strainer, it is clogged. Clean strainer.			☐	☐
g.	Clean condensor coil.			☐	☐
h.	If condensor 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 from shell/tubes on water condensors.			☐	☐
j.	Repair suction valves in compressor, if needed.			☐	☐
11. Multiple parallel chillers have no isolation schedule for extended light-load operation.		☐	☐		
a.	Develop load vs. capacity matrix.			☐	☐
b.	Isolate unneeded chillers.			☐	☐
12. Steam, hot or chilled water leaks are evident.		☐	☐		
a.	Repair leaks.			☐	☐
13. Steam, hot or chilled water valves do not shut off tight.		☐	☐		
a.	Repair or replace valve.			☐	☐

HVAC - VENTILATION		Problem?		Recommended?	
		Yes	No	Yes	No
1. Air flow to space feels unusually low is unconsistent from one space to another.		☐	☐		
a.	Utilize ductwork access openign to check for any obstructions such as loose hanging insulation, loose turning vanes and accessories, and closed volume or fire dampers. Adjust, repair, or replace as necessary.			☐	☐
b.	Inspect all room outlets and inlets. They should be kept clean and free of all dirt and obstructions.			☐	☐
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.			☐	☐
2. Large spaces having low occupancy are maintained at comfort conditions.		☐	☐		
a.	Reduce thermostat settings in winter, raise settings in summer.			☐	☐
b.	Consider regrouping activities into smaller areas which can be conditioned separately from remainder of buildign.			☐	☐
3. Heating/cooling equipment is operating in lobbies, corridors, vestibules, and/or other public areas.		☐	☐		
a.	Lower heating set points in the above areas if there is no possibility of freeze-up.			☐	☐
b.	Properly adjust and balance air/water systems and controls.			☐	☐
4. An excessive quantity of outdoor air is used to ventilate the building.		☐	☐		
a.	Reduce outdoor air quantity to the minimum allowed by codes by adjusting outdoor air dampers.			☐	☐
b.	Repair any malfunctioning ventilation equipment.			☐	☐
c.	Replace old-style dampers with new high quality opposed-blade models with better close-off ratings.			☐	☐
d.	Repair leaking or faulty dampers.			☐	☐

HVAC - VENTILATION		Problem?		Recommended?	
		Yes	No	Yes	No
5. Outdoor air intake dampers open when building is unoccupied.		☐	☐		
a.	Close outdoor air dampers when building is unoccupied. Be sure dampers have proper seals.			☐	☐
b.	Install controls which will automatically close dampers during unoccupied periods.			☐	☐
6. Return, outdoor air and exhaust dampers are not sequencing properly.		☐	☐		
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.	Replace old-style dampers with new high quality opposed-blade models with better close-off ratings.			☐	☐
7. Ventilation systems are not utilized for natural cooling capability.		☐	☐		
a.	Whenever possible, use outdoor air for cooling rather than using refrigeration.			☐	☐
b.	Install an economizer cycle with enthalpy control to optimize use of outside air for cooling.			☐	☐

DOMESTIC HOT WATER		Problem?		Recommended?	
		Yes	No	Yes	No
1. Hot water temperature is excessive.		☐	☐		
a.	Lower thermostat or controller set point to 105-115 °F for general purposes.			☐	☐
2. System insulation is damaged or missing.		☐	☐		
a.	Repair, replace. Protect to prevent recurrence of damage.			☐	☐
3. Water temperatures are not reduced during unoccupied periods.		☐	☐		
a.	Schedule setbacks (either manually or with existing time clock). Consider schedule's impact on electrical demand.			☐	☐
b.	Install an appropriate automatic control device.			☐	☐
4. Water leaks are evident.		☐	☐		
a.	Repair leaks and defective faucets.			☐	☐
5. Heat pump water heater coils are not maintained on scheduled basis.		☐	☐		
a.	Schedule maintenance following manufacturer's recommendations.			☐	☐
6. Hot water recirculating pumps run continuously.		☐	☐		
a.	Develop operating schedule to match occupancy.			☐	☐
7. Drips or leaks are evident in hot water systems.		☐	☐		
a.	Repair all leaks including those of the faucets and pumps.			☐	☐

DOMESTIC HOT WATER		Problem?		Recommended?	
		Yes	No	Yes	No
8. Electric water heater has no time restrictions on heating cycle.		☐	☐		
a.	Utilize "vacation cycle" on water heater when not needed during extended periods. (Note: Complete deactivation could cause leaks)			☐	☐
b.	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 loads.			☐	☐
9. Devices to conserve heated water have not been utilized where practical.		☐	☐		
a.	Install mixing valves.			☐	☐
b.	Replace standard faucets with self-closing, flow restrictor valves.			☐	☐
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.			☐	☐
10. Storage tanks, piping and water heaters are utilized inefficiently.		☐	☐		
a.	Install a small domestic hot water heater to maintain desired temperature in water storage tank.			☐	☐
b.	Install de-centralized water heating.			☐	☐

BUILDING OCCUPANCY		Problem?		Recommended?	
		Yes	No	Yes	No
1. Off-hour activities extend operating hours for energy using systems.		☐	☐		
a.	Reschedule off-hour activities to accommodate partial shutdown of building.			☐	☐
b.	Reschedule custodial and cleaning activities during working hours whenever possible.			☐	☐
2. Building has extended occupancy areas such as computer rooms.		☐	☐		
a.	Isolate these spaces from the portion of the building having fewer operating hours.			☐	☐

Appendix D - Economic Analysis Calculations

List of Tables

Table D-1 Initial Costs

Item	Initial Cost								
	Reference	Page #	Material			Labor		Total	
Aluminum Windows, Double Pane	Gen*	p.262	$	355.00	Each	$	77.50	$	432.50
Aluminum Windows, Single Pane	Gen*	p.262	$	198.00	Each	$	77.50	$	275.50
Steel Windows, Double Pane	Gen*	p.428	$	220.00	Each	$	81.50	$	301.50
Steel Windows, Single Pane	Gen*	p.428	$	118.00	Each	$	81.50	$	199.50
Wood Windows, Double Pane	Gen*	p.264	$	276.00	Each	$	34.50	$	310.50
Wood Windows, Single Pane	Gen*	p.264	$	225.00	Each	$	34.50	$	259.50
Interior Hollow Metal Steel Door, 3'x7'	Gen*	p.239	$	345.00	Each	$	40.50	$	385.50
Exterior Hollow Metal Steel Door, 3'x7'	Gen*	p.241	$	415.00	Each	$	49.00	$	464.00
Avg 30-40 Gallon, Gas-Fired Water Heater	Plumb*	p.451	$	1,762.50	Each	$	1,400.00	$	3,162.50
5 Gallon Water Heater, Electric	Gen*	p.472	$	2,350.00	Each	$	214.00	$	2,564.00
10 Gallon Water Heater, Electric	Gen*	p.472	$	2,600.00	Each	$	214.00	$	2,814.00
Instananeous Water Heater, 6 Gal Electric	Plumb*	p.269	$	650.00	Each	$	172.00	$	822.00
Instananeous Water Heater, 10 Gal Electric	Plumb*	p.269	$	690.00	Each	$	172.00	$	862.00
Caulking, Latex Acrylic Based, 1/4"x1/4"	Gen*	p.233	$	0.09	LF	$	1.15	$	1.24
Caulking, Latex Acrylic Based, 3/8"x3/8"	Gen*	p.233	$	0.21	LF	$	1.22	$	1.43
Caulking, Polyurethane, 1/4"x1/4"	Gen*	p.233	$	0.16	LF	$	1.15	$	1.31
Fluorescent, Recessed, 2'x4', (2) 32W T8	Gen*	p.550	$	72.50	Each	$	76.00	$	148.50
Fluorescent, Recessed, 2'x4', (3) 32W T8	Gen*	p.550	$	76.50	Each	$	80.50	$	157.00
Fluorescent, Recessed, 2'x4', (4) 32W T8	--	--		--	--		--		--
Fluorescent, 4' long, T8 30W lamp	Gen*	p.553	$	8.95	Each	$	4.45	$	13.40
Fluorescent, 4' long, T5 28W lamp	Gen*	p.554	$	12.25	Each	$	4.45	$	16.70
Fluorescent, 4' long, T5 54W lamp	Gen*	p.554	$	17.75	Each	$	4.45	$	22.20
Fluorescent, Strip, 4' long, 2 lamp	--	--		--	--		--		--
Fluorescent, Strip, 8' long, 1 lamp	--	--		--	--		--		--
Fluorescent, Strip, 8' long, 2 lamp	--	--		--	--		--		--
25W Compact Fluorescent Lamp	Hardware	--	$	2.74	Each	$	4.45	$	7.19
100W A-Lamp	Hardware	--	$	1.37	Each	$	4.45	$	5.82
0.5 GPF Wall-Hung Urinal	Plumb*	p.280	$	645.00	Each	$	257.00	$	902.00
1.28 GPF Floor-Mounted Water Closet	Plumb*	p.280	$	555.00	Each	$	133.00	$	688.00
0.5 GPM Lavatory Faucet	Plumb*	p.278	$	44.50	Each	$	43.00	$	87.50
Thermostat, 24 hour, automatic, clock	Elec*	p.80	$	137.00	Each	$	51.50	$	188.50
Thermostat, Electric, Low Voltage, 2 Wire	Elec*	p.80	$	32.50	Each	$	31.00	$	63.50
Thermostat, Electric, Low Voltage, 3 Wire	Elec*	p.80	$	31.50	Each	$	40.00	$	71.50
Unit Ventilator, day/night operation, ASHRAE	Mech*	p.489	$	2,675.00	Each	$	1,300.00	$	3,975.00

* Reference denotes the RS Means book utilized to find values.

Table D-2 Maintenance Costs

Item	Maintenance Cost					
	Material	Labor	Total	Description	Freq. (Yrs)	Total/Yr
Aluminum Windows, Double Pane	$ 1.62	$ 63.39	$ 65.01	Refinish	5	$ 13.00
Aluminum Windows, Single Pane	$ 1.62	$ 63.39	$ 65.01	Refinish	5	$ 13.00
Steel Windows, Double Pane	$ 1.62	$ 63.39	$ 65.01	Refinish	5	$ 13.00
Steel Windows, Single Pane	$ 1.62	$ 63.39	$ 65.01	Refinish	5	$ 13.00
Wood Windows, Double Pane	$ 1.62	$ 63.39	$ 65.01	Refinish	5	$ 13.00
Wood Windows, Single Pane	$ 1.62	$ 63.39	$ 65.01	Refinish	5	$ 13.00
Interior Hollow Metal Steel Door, 3'x7'	$ 11.50	$ 31.88	$ 43.38	Refinish	4	$ 10.85
Exterior Hollow Metal Steel Door, 3'x7'	$ 11.50	$ 31.88	$ 43.38	Refinish	4	$ 10.85
Average 30-40 Gallon, Gas-Fired Water Heater	--	$ 1.83	$ 1.83	Check-Up	3	$ 0.61
5 Gallon Water Heater, Electric	--	$ 1.83	$ 1.83	Check-Up	3	$ 0.61
10 Gallon Water Heater, Electric	--	$ 1.83	$ 1.83	Check-Up	3	$ 0.61
Instananeous Water Heater, 6 Gallon Electric	--	$ 1.83	$ 1.83	Check-Up	3	$ 0.61
Instananeous Water Heater, 10 Gallon Electric	--	$ 1.83	$ 1.83	Check-Up	3	$ 0.61
Caulking, Latex Acrylic Based, 1/4"x1/4"	$ 3.41	$ 8.23	$ 11.64	Re-Caulk	20	$ 0.58
Caulking, Latex Acrylic Based, 3/8"x3/8"	$ 3.41	$ 8.23	$ 11.64	Re-Caulk	20	$ 0.58
Caulking, Polyurethane, 1/4"x1/4"	$ 3.41	$ 8.23	$ 11.64	Re-Caulk	20	$ 0.58
Fluorescent, Recessed, 2'x4', (2) 32W T8	$ 7.70	$ 15.22	$ 22.92	Replace	10	$ 2.29
Fluorescent, Recessed, 2'x4', (3) 32W T8	$ 7.70	$ 15.22	$ 22.92	Replace	10	$ 2.29
Fluorescent, Recessed, 2'x4', (4) 32W T8	$ 7.70	$ 15.22	$ 22.92	Replace	10	$ 2.29
Fluorescent, 4' long, T8 30W lamp	$ 7.70	$ 15.22	$ 22.92	Replace	10	$ 2.29
Fluorescent, 4' long, T5 28W lamp	$ 7.70	$ 15.22	$ 22.92	Replace	10	$ 2.29
Fluorescent, 4' long, T5 54W lamp	$ 7.70	$ 15.22	$ 22.92	Replace	10	$ 2.29
Fluorescent, Strip, 4' long, 2 lamp	$ 7.70	$ 15.22	$ 22.92	Replace	10	$ 2.29
Fluorescent, Strip, 8' long, 1 lamp	$ 7.70	$ 15.22	$ 22.92	Replace	10	$ 2.29
Fluorescent, Strip, 8' long, 2 lamp	$ 7.70	$ 15.22	$ 22.92	Replace	10	$ 2.29
25W Compact Fluorescent Lamp	$ 7.70	$ 15.22	$ 22.92	Replace	10	$ 2.29
100W A-Lamp	$ 7.70	$ 15.22	$ 22.92	Replace	10	$ 2.29
Thermostat, 24 hour, automatic, clock	--	--	--	--	--	--
Thermostat, Electric, Low Voltage, 2 Wire	--	--	--	--	--	--
Thermostat, Electric, Low Voltage, 3 Wire	--	--	--	--	--	--
Unit Ventilator, day/night operation, ASHRAE	$ 285.00	$ 179.90	$ 464.90	Repair	10	$ 46.49

Table D-3 Annual Energy Costs

Item	**Annual Energy Cost**
Window Type	**Annual Energy**
Single-Pane Window (3'-0" x 3'-0" window)	$ 2.70
Double-Pane Window (3'-0" x 3'-0" window)	$ 0.90
Plumbing Fixture	**Annual Water Cost**
0.5 GPF Urinal	$ 10.80
1.5 GPF Urinal	$ 32.40
1.28 GPF Water Closet	$ 27.64
1.6 GPF Water Closet	$ 34.56
0.5 GPM Lavatory Faucet	$ 10.80
1.5 GPM Lavatory Faucet	$ 32.40

* Software from DOE website

Assumptions:

Water Costs: $4.00/1000 Gallons.

Window Energy: Calculated in Chapter 8, assuming 10 hours, 5 days a week, and 6 months of heating operation at $4.00/dekatherm. Using a 3'-0" x 3'-0" window.

Table D-4 Demolition Costs

Item	Demolition Cost				
	Book	Page #	Material	Labor	Total
Aluminum Windows, Double Pane	--	--	--	--	--
Aluminum Windows, Single Pane	General	p.236	--	$ 17.20	$ 17.20
Steel Windows, Double Pane	--	--	--	--	--
Steel Windows, Single Pane	General	p.236	--	$ 21.00	$ 21.00
Wood Windows, Double Pane	--	--	--	--	--
Wood Windows, Single Pane	General	p.236	--	$ 12.50	$ 12.50
Interior Hollow Metal Steel Door, 3'x7'	--	--	--	--	--
Exterior Hollow Metal Steel Door, 3'x7'	--	--	--	--	--
Average 30-40 Gallon, Gas-Fired Water Heater	General	p.453	--	$ 71.50	$ 71.50
5 Gallon Water Heater, Electric	General	p.453	--	$ 71.50	$ 71.50
10 Gallon Water Heater, Electric	General	p.453	--	$ 71.50	$ 71.50
Instananeous Water Heater, 6 Gallon Electric	General	p.453	--	$ 71.50	$ 71.50
Instananeous Water Heater, 10 Gallon Electric	General	p.453	--	$ 71.50	$ 71.50
Caulking, Latex Acrylic Based, 1/4"x1/4"	--	--	--	--	--
Caulking, Latex Acrylic Based, 3/8"x3/8"	--	--	--	--	--
Caulking, Polyurethane, 1/4"x1/4"	--	--	--	--	--
Fluorescent, Recessed, 2'x4', (2) 32W T8	General	p.525	--	$ 24.50	$ 24.50
Fluorescent, Recessed, 2'x4', (3) 32W T8	--	--	--	--	--
Fluorescent, Recessed, 2'x4', (4) 32W T8	General	p.525	--	$ 27.00	$ 27.00
Fluorescent, 4' long, T8 30W lamp	General	p.525	--	$ 15.20	$ 15.20
Fluorescent, 4' long, T5 28W lamp	General	p.525	--	$ 15.20	$ 15.20
Fluorescent, 4' long, T5 54W lamp	General	p.525	--	$ 15.20	$ 15.20
Fluorescent, Strip, 4' long, 2 lamp	General	p.525	--	$ 16.10	$ 16.10
Fluorescent, Strip, 8' long, 1 lamp	General	p.525	--	$ 19.15	$ 19.15
Fluorescent, Strip, 8' long, 2 lamp	General	p.525	--	$ 20.00	$ 20.00
25W Compact Fluorescent Lamp	--	--	--	--	--
100W A-Lamp	General	p.525	--	$ 5.00	$ 5.00
0.5 GPF Wall-Hung Urinal	Plumb	p.99	--	$ 61.50	$ 61.50
1.28 GPF Floor-Mounted Wall Closet	Plumb	p.99	--	$ 53.50	$ 53.50
0.5 GPM Lavatory Faucet	Plumb	p.99	--	$ 43.00	$ 43.00
Thermostat, 24 hour, automatic, clock	--	--	--	--	--
Thermostat, Electric, Low Voltage, 2 Wire	--	--	--	--	--
Thermostat, Electric, Low Voltage, 3 Wire	--	--	--	--	--
Unit Ventilator, day/night operation, ASHRAE	General	p.486	--	$ 865.00	$ 865.00

Note: Blank cells indicate no demolition cost included.

Table D-5 Linear Fluorescent Example Calculation

Net Present Cost Calculation

Replacement of a T12 lamp fixture with T5 lamp fixture

T5 lamp First Cost	$109.50	Life:	20	Yrs
		Interest Rate:	6	%
ual Maintenance Cost:	$4.58			
Annual Energy Cost:	$12.24			
Demo Cost:	$15.20			
Salvage Cost:	$0.00			

NPC = (Item's First Cost) + (Annual Maintenance Cost)(P/A,i,n) + (Annual Energy Cost)(P/A,i,n) + (Demo Cost)(P/F,i,n) - (Salvage Cost)

NPC = $351.17

Definitions/Assumptions:

First Cost: Initial Cost of Equipment for Purchasing and Installing
Annual Maintenance Cost: Annual Costs Associated with Maintenance
Annual Energy Cost Difference: Difference between existing cost and new annual energy cost
Demolition Cost: The cost at the end of an item's life to remove it
Salvage Cost: When an item has died and requires replacing, this is the value of the salvaged parts.
Electricity: Assumed rate of $0.07 kWh. Use regional applicable rate.
T12: Lamp First Cost: $0 because already existing, Annual Energy Cost: $23.58

Economic Analysis Equations: (Newman, 2011)

P: Present Cost, F: Future Cost, A: Annual Cost, i: Interest Rate, n: Years
Present Cost given Future Cost: (P/F, i, n) = F * (1+i)^n
Present Cost given Annual Costs: (P/A, i, n) = A*((((1+i)^n)-1)/(i(1+i)^n))

Payback Period

Payback = ΔP = (Difference in Initial Item Costs)
ΔA = (Difference in Annual Costs)

Payback = ΔP = |(0-109.50)|
ΔA = (23.58-12.24)

Payback = **9.66** years

Table D-6 NPC and Payback Calculations for Aluminum Windows

Net Present Worth Calculation - Aluminum Windows, Double-Pane, One Window				
Item's First Cost	$ 432.50	Life:	20	Yrs
		Interest Rate:	6	%
Maintenance Cost:	$ 13.00			
Annual Energy Cost:	$ 0.90			
NPW =	$ 591.93			
Net Present Worth Calculation - Aluminum Windows, Single-Pane, One Window				
Item's First Cost	$ -	Life:	20	Yrs
		Interest Rate:	6	%
Maintenance Cost:	$ 13.00			
Annual Energy Cost:	$ 2.70			
Demolition Cost:	$ 17.20			
NPW =	$ 235.24			
Aluminum Windows, Double vs. Single Pane				
Payback =	ΔP			
	ΔA			
Payback =	|(0.00-432.50)|			
	(2.70-0.90)			
Payback =	240.28	Years		

Table D-7 NPC and Payback Calculations for Steel Windows

Net Present Worth Calculation - Steel Windows, Double-Pane, One Window					
Item's First Cost	$ 301.50		Life:	20	Yrs
			Interest Rate:	6	%
Maintenance Cost:	$ 13.00				
Annual Energy Cost:	$ 0.90				
	NPW =	$ 460.93			
Net Present Worth Calculation - Steel Windows, Single-Pane, One Window					
Item's First Cost	$ -		Life:	20	Yrs
			Interest Rate:	6	%
Maintenance Cost:	$ 13.00				
Annual Energy Cost:	$ 2.70				
Demolition Cost;	$ 21.00				
	NPW =	$ 247.43			
Steel Windows, Double vs. Single-Pane					
Payback =	ΔP				
	ΔA				
Payback =	|(0.00-301.50)|				
	(2.70-0.90)				
Payback =	167.50	years			

Table D-8 NPC and Payback Calculations for Wood Windows and Metal Doors

Net Present Worth Calculation - Wood Windows, Double-Pane, One Window

Item's First Cost	$ 310.50	Life:	20	Yrs
		Interest Rate:	6	%
Maintenance Cost:	$ 13.00			
Annual Energy Cost:	$ 0.90			

NPW = $ 469.93

Net Present Worth Calculation - Wood Windows, Single-Pane, One Window

Item's First Cost	$ -	Life:	20	Yrs
		Interest Rate:	6	%
Maintenance Cost:	$ 13.00			
Annual Energy Cost:	$ 2.70			
Demolition Cost:	$ 12.50			

NPW = $ 220.17

Wood Windows, Double vs. Single Pane

Payback = $\frac{\Delta P}{\Delta A}$

Payback = $\frac{|(0.00-301.50)|}{(2.70-0.90)}$

Payback = 172.50 years

Net Present Worth Calculation - Interior Metal Door

Item's First Cost	$ 385.50	Life:	20	Yrs
		Interest Rate:	6	%
Maintenance Cost:	$ 10.85			

NPW = $ 509.95

Net Present Worth Calculation - Exterior Metal Door

Item's First Cost	$ 464.00	Life:	20	Yrs
		Interest Rate:	6	%
Maintenance Cost:	$ 10.85			

NPW = $ 588.45

Table D-9 NPC Calculations for Sealant and Lighting

Net Present Worth Calculation - Caulking, Latex Acrylic Based, 1/4"x1/4"

Item's First Cost	$ 1.24	per LF	Life:	20	Yrs
			Interest Rate:	6	%
Maintenance Cost:	$ 0.58				
Annual Energy Cost:	$ -				
	NPW =	$ 7.89			

Net Present Worth Calculation - Caulking, Latex Acrylic Based, 3/8"x3/8"

Item's First Cost	$ 1.43	per LF	Life:	20	Yrs
			Interest Rate:	6	%
Maintenance Cost:	$ 0.58				
Annual Energy Cost:	$ -				
	NPW =	$ 8.08			

Net Present Worth Calculation - Caulking, Polyurethane, 1/4"x1/4"

Item's First Cost	$ 1.31	per LF	Life:	20	Yrs
			Interest Rate:	6	%
Maintenance Cost:	$ 0.58				
Annual Energy Cost:	$ -				
	NPW =	$ 7.96			

Net Present Worth Calculation - Fluorescent, Recessed, 2'x4', (2) 32W T8

Item's First Cost	$ 148.50		Life:	20	Yrs
			Interest Rate:	6	%
Maintenance Cost:	$ 2.29				
Annual Energy Cost:	$ 13.98				
Demo Cost:	$ 24.50				
	NPW =	$ 413.66			

Net Present Worth Calculation - Fluorescent, Recessed, 2'x4', (3) 32W T8

Item's First Cost	$ 157.00		Life:	20	Yrs
			Interest Rate:	6	%
Maintenance Cost:	$ 2.29				
Annual Energy Cost:	$ 20.97				
Demo Cost:	$ 27.00				
	NPW =	$ 510.34			

Table D-10 NPC and Payback Calculations for Lighting

Net Present Worth Calculation - Fluorescent, 4' long, (2) T8 30W lamp fixture					
Item's First Cost	$ 109.50		Life:	20	Yrs
			Interest Rate:	6	%
Maintenance Cost:	$ 4.58				
Annual Energy Cost:	$ 13.10				
Demo Cost:	$ 15.20				
	NPW =	$ 361.08			
Payback Period - T12 & T8					
Payback =	ΔP				
	ΔA				
Payback =	|(0-109.50)|				
	(23.59-13.10)				
Payback =	10.45	years			
Net Present Worth Calculation - Fluorescent, 4' long, (2) T5 28W lamp fixture					
Item's First Cost	$ 109.50		Life:	20	Yrs
			Interest Rate:	6	%
Maintenance Cost:	$ 4.58				
Annual Energy Cost:	$ 12.24				
Demo Cost:	$ 15.20				
	NPW =	$ 351.17			
Payback Period - T12 & T5					
Payback =	ΔP				
	ΔA				
Payback =	|(0-109.50)|				
	(23.59-12.24)				
Payback =	9.65	years			
Net Present Worth Calculation - Fluorescent, 4' long, T12 54W lamp fixture					
Item's First Cost	$ -		Life:	20	Yrs
			Interest Rate:	6	%
nual Maintenance Cost:	$ 4.58				
Annual Energy Cost:	$ 23.59				
Demo Cost:	$ 15.20				
	NPW =	$ 371.82			

Table D-11 NPC and Payback Calculations for CFLs and Incandescents

Net Present Worth Calculation - Compact Fluorescent, 25W					
Item's First Cost	$ 7.19		Life:	20	Yrs
			Interest Rate:	6	%
Maintenance Cost:	$ 2.29				
Annual Energy Cost:	$ 5.84				
Demo Cost:	$ 5.00				
	NPW =	$ 116.48			
Net Present Worth Calculation - Incandescent A-Lamp, 100W					
Item's First Cost	$ -		Life:	20	Yrs
			Interest Rate:	6	%
Maintenance Cost:	$ 2.29				
Annual Energy Cost:	$ 23.36				
Demo Cost:	$ 5.00				
	NPW =	$ 310.24			
Payback Period - CFL and Incandescent					
Payback =	ΔP				
	ΔA				
Payback =	|(0.00-7.19)|				
	(23.36-5.84)				
Payback =	0.41	years			

Table D-12 NPC Calculations for Controls

Net Present Worth Calculation - Thermostat, 24 hour, automatic, clock

Item's First Cost	$ 188.50	Life:	20	Yrs
		Interest Rate:	6	%
Maintenance Cost:	$ -			
Annual Utility Cost:	$ -			
NPW =	$ 188.50			

Net Present Worth Calculation - Thermostat, Electric, Low Voltage, 2 Wire

Item's First Cost	$ 63.50	Life:	20	Yrs
		Interest Rate:	6	%
Maintenance Cost:	$ -			
Annual Utility Cost:	$ -			
NPW =	$ 63.50			

Net Present Worth Calculation - Thermostat, Electric, Low Voltage, 3 Wire

Item's First Cost	$ 71.50	Life:	20	Yrs
		Interest Rate:	6	%
Maintenance Cost:	$ -			
Annual Utility Cost:	$ -			
NPW =	$ 71.50			

Net Present Worth Calculation - Clock Dial Time Switch, 24 hour, w/ enclosure

Item's First Cost	$ 173.00	Life:	20	Yrs
		Interest Rate:	6	%
Maintenance Cost:	$ -			
Annual Utility Cost:	$ -			
NPW =	$ 173.00			

Net Present Worth Calculation - Unit Ventilator, day/night operation, ASHRAE

Item's First Cost	$ 3,975.00	Life:	20	Yrs
		Interest Rate:	6	%
Maintenance Cost:	$ 46.49			
Annual Energy Cost:	$ -			
Demo Cost:	$ 865.00			
NPW =	$ 7,282.41			

Table D-13 NPC and Payback Calculations for Urinals

Net Present Worth Calculation - 0.5 GPF Wall Hung Urinal

Item's First Cost	$ 902.00	Life:	20	Yrs
		Interest Rate:	6	%
Maintenance Cost:	$ -			
Annual Energy Cost:	$ 10.80			
		* Assuming $4.00/1000gal		
Demo Cost:	$ -			
NPW =	$ 1,025.88			

Net Present Worth Calculation - In-Place Urinals

Item's First Cost	$ -	Life:	20	Yrs
		Interest Rate:	6	%
Maintenance Cost:	$ -			
Annual Energy Cost:	$ 32.40			
		* Assuming $4.00/1000gal		
Demo Cost:	$ 61.50			
NPW =	$ 568.86			

Payback Period - Replacing a Urinal

$$\text{Payback} = \frac{\Delta P}{\Delta A}$$

$$\text{Payback} = \frac{|(0.00-902.00)|}{(32.40-10.80)}$$

Payback = 41.76 Years

Table D-14 NPC and Payback Calculations for Water Closets

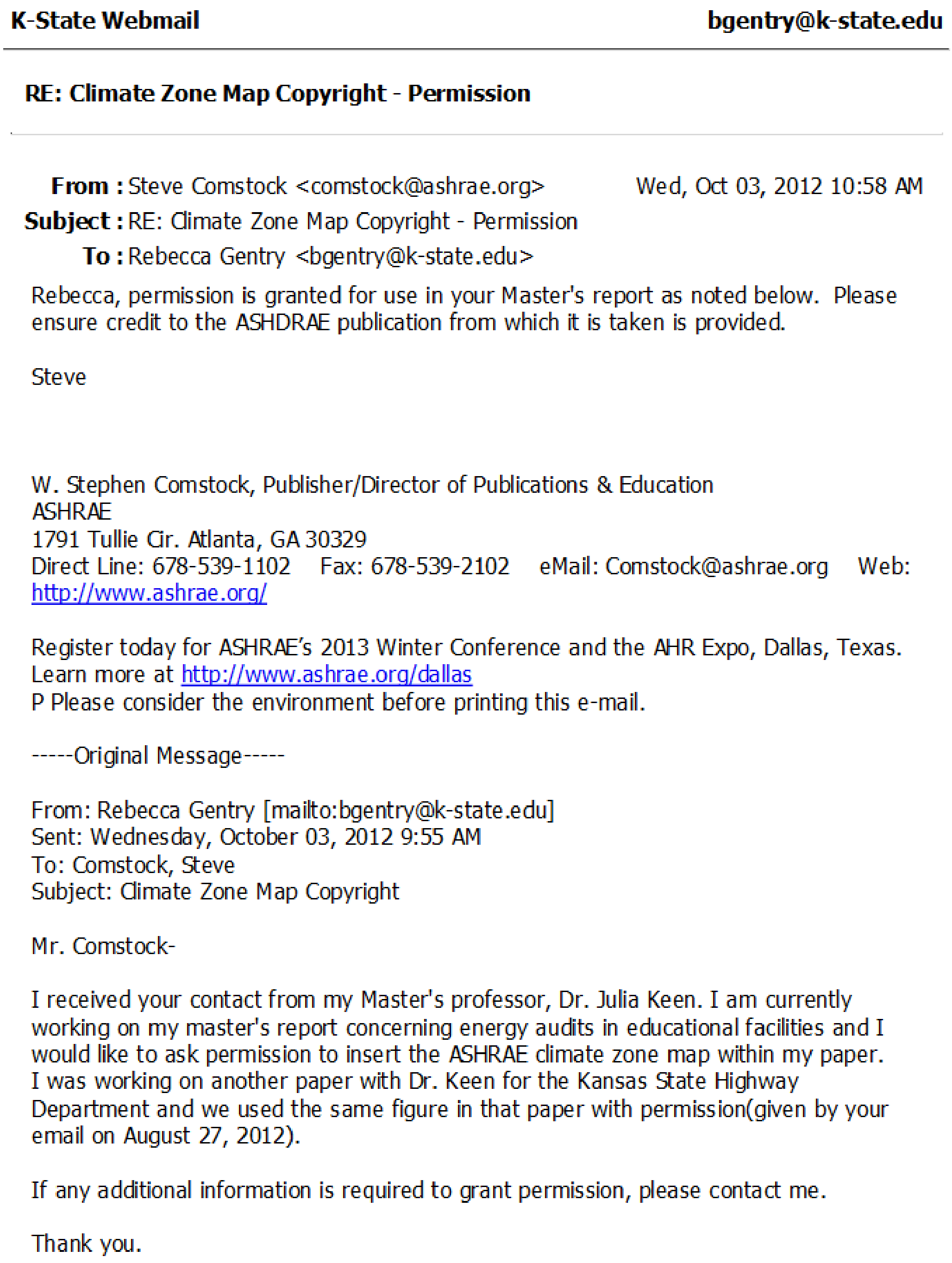
	Net Present Worth Calculation - 1.28 Floor-Mounted Water Closet					
	Item's First Cost	$ 688.00		Life:	20	Yrs
				Interest Rate:	6	%
	Maintenance Cost:	$ -				
	Annual Energy Cost:	$ 27.65				
				* Assuming $4.00/1000gal		
	Demo Cost:	$ -				
		NPW =	$ 1,005.14			
	Net Present Worth Calculation - In-Place Water Closet					
	Item's First Cost	$ -		Life:	20	Yrs
				Interest Rate:	6	%
	Maintenance Cost:	$ -				
	Annual Energy Cost:	$ 34.56				
				* Assuming $4.00/1000gal		
	Demo Cost:	$ 53.50				
		NPW =	$ 567.98			
	Payback Period - Replacing a Water Closet					
	Payback =	ΔP				
		ΔA				
	Payback =	|(0.00-688.00)|				
		(34.56-27.65)				
	Payback =	99.57	Years			

Table D-15 NPC and Payback Calculations for Lavatory Faucets

Net Present Worth Calculation - 0.5 GPM Lavatory Faucet					
Item's First Cost	$ 87.50		Life:	20	Yrs
			Interest Rate:	6	%
Maintenance Cost:	$ -				
Annual Energy Cost:	$ 10.80				
			* Assuming $4.00/1000gal		
Demo Cost:	$ -				
	NPW =	$ 211.38			
Net Present Worth Calculation - In-Place Lavatory Faucet					
Item's First Cost	$ -		Life:	20	Yrs
			Interest Rate:	6	%
Maintenance Cost:	$ -				
Annual Energy Cost:	$ 32.40				
			* Assuming $4.00/1000gal		
Demo Cost:	$ 43.00				
	NPW =	$ 509.53			
Payback Period - Replacing a Lavatory Faucet					
Payback =	ΔP				
	ΔA				
Payback =	|(0.00-87.50)|				
	(32.40-10.80)				
Payback =	4.051	Years			

Appendix E - Copyright Permission

Copyright permission for Figure 3-1:



K-State Webmail **bgentry@k-state.edu**

RE: Climate Zone Map Copyright - Permission

From : Steve Comstock <comstock@ashrae.org> Wed, Oct 03, 2012 10:58 AM
Subject : RE: Climate Zone Map Copyright - Permission
To : Rebecca Gentry <bgentry@k-state.edu>

Rebecca, permission is granted for use in your Master's report as noted below. Please ensure credit to the ASHDRAE publication from which it is taken is provided.

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From: Rebecca Gentry [mailto:bgentry@k-state.edu]
Sent: Wednesday, October 03, 2012 9:55 AM
To: Comstock, Steve
Subject: Climate Zone Map Copyright

Mr. Comstock-

I received your contact from my Master's professor, Dr. Julia Keen. I am currently working on my master's report concerning energy audits in educational facilities and I would like to ask permission to insert the ASHRAE climate zone map within my paper. I was working on another paper with Dr. Keen for the Kansas State Highway Department and we used the same figure in that paper with permission(given by your email on August 27, 2012).

If any additional information is required to grant permission, please contact me.

Thank you.