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Energy Audits Of State Buildings In Alabama

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ENERGY AUDITS OF STATE BUILDINGS IN ALABAMA

by

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ABSTRACT

The purpose of this project was to perform preliminary energy audits at various state buildings in Alabama. Energy audits were conducted for a total of 18 buildings at the Department of Youth Services (Chalkville campus) and the Alabama State Capitol complex. Facility reports and summaries were prepared with the help of data obtained from building managers. Our research team identified areas in these facilties where energy conservation could be employed at no or low cost. The energy savings resulting from these audits were estimated based upon the guidelines presented in the Science Technology and Energy Division Guide for Calculating Program Annual Energy Savings, published in 2003. The estimated energy savings for the Chalkville site is approximately 9,000 million BTUs, with an associated economic savings of approximately $60,000. The estimated energy savings for the Alabama State Capitol complex buildings is approximately 3,400 million BTUs, with an associated economic savings of $22,000.

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LIST OF ABBREVIATIONS

AC	Air conditioning
ADECA	Alabama Department of Economic and Community Affairs
AFUE	Annual fuel utilization efficiency
ASHRAE	American Society of Heating, Refrigeration and Air-Cooling Engineers
BPM	Building property management
BTU	British thermal unit
CFLs	Compact fluorescent lights
CO_2	Carbon dioxide
CO	Carbon monoxide
DEGREE (F)	Degree fahrenheit
DGS	Department of General Services
ECM	Energy conservation measures
ECO	Energy conservation opportunities
EER	Energy efficiency ratio
EMS	Energy management system
ESCO	Energy service contracting organization
EUI	Energy use index
Fc	Foot candle
GRHC	Green Roofs for Healthy Cities

LIST OF ABBREVIATIONS (Continued)

HVAC	Heating ventilation and cooling
KW	Kilowatt
lbs	Pounds
LCD	Liquid crystal display
LED	Light emitting diode
m/s	meter/second
mA	milli ampere
MW	Mega watt
O & M	Operating & maintenance
PC	Personal computer
PLR	Peak load reduction
ppm	parts per million
PSE	particle size efficiency
RH	Relative humidity
SEER	Seasonal energy efficiency ratio
SHGC	Solar heat gain coefficient
SMUD	Sacramento Municipal Utility District
Sqft	square feet
V	Volts
VFD	Variable frequency drives
W or kWh	Watt or kilowatt hour

CHAPTER 1

INTRODUCTION

As a result of economic growth and shifts in the composition of economic activity over the past two decades, there has been a major increase in commercial activity in the United States. This has led to an increase in demand for energy.

The nation's 81 million buildings consume more energy than any other sector of the U.S. economy, including transportation and industry [1]. The diversity of building types and functions results in a broad range of energy use. Though the overall intensity of energy use has declined slightly in recent years, the intensity of electricity use has increased substantially. Air conditioning is the fastest growing use for electricity and creates peaks in electricity demand [2]. Approximately 50% of the cost of a commercial building lies in operation and maintenance expenses over a 40-year life, according to the American Society of Heating, Refrigeration and Air-Conditioning Engineers [3]. Early and thoughtful investments in efficient building envelope materials (doors, windows, exterior, and roof), Heating, ventilating, and air conditioning (HVAC) systems, lighting, and office equipment can yield significant long-term savings as compared to existing buildings.

The buildings sector consumes nearly one-third of the nation's primary energy and is responsible for a significant proportion of carbon dioxide, sulfur dioxide, and nitrogen oxide emissions. State and local governments own and lease millions of square feet of space. By implementing energy efficiency retrofits in existing buildings and designing new buildings to energy, and resource-efficient "green" standards, state governments can create significant energy savings and reduce greenhouse gas emissions. States can use energy efficiency as a pollution prevention strategy. These results benefit state taxpayers, building occupants, building operators, and the environment [4].

A wide range of energy-efficient products have been developed and manufactured but are not widely adopted. For example, replacing incandescent bulbs with compact fluorescent lamps wherever possible can save up to 66% of total energy used in lighting. Similar efficiency improvements are available in equipment that provides refrigeration and other energy services. Significant amounts of energy and money can be saved in commercial and industrial buildings, especially in state and local government buildings, through the proper operation and maintenance of energy systems and by implementation of well-planned retrofit projects. Thousands of existing buildings have been retrofitted or modified to produce energy savings as high as 50% as compared to those buildings where energy audits were not conducted [2].

In 2001, state office buildings in California cut energy use by an average of 22%, including a 26% reduction in one month. California's Department of General Services benchmarked 35 buildings in 2001. One building was awarded the Energy Star rating in

2001 and two more earned the Energy Star rating in 2002. A new state complex in Sacramento, the Capitol Area East End, is expected to save $429,000 annually in energy costs as a result of its sustainable and energy-efficient design and construction. The strongest energy-efficiency building standards in the country went into effect in California in 2001. In five years, energy savings from these standards are expected to reach 1,000 megawatts (MW) or 947 817.12 Btu/s, a year — enough energy to power an estimated 750,000 homes annually [5].

Over the past few years, energy conservation has become an established fact of life, buttressed by experience and continuing research by government, corporate, and academic institutions. This process has given rise to a new discipline among engineers and architects called energy management. There are several firms that have trained personnel to carry out energy audits varying from a one-day walk-through audit to a month-long detailed audit.

Why an Energy Management Program? What is this program? What is involved in this program and how much does it cost? How long does it take? What are the benefits a building owner gets when he hires a professional energy consultant? An energy management program is a systematic, ongoing strategy for controlling a building's fuel consumption patterns in such a way that it reduces energy use to the absolute minimum permitted by the climate in which the building is located, as well as conditions of the building and other related factors. The first and the most important step in a full-scale energy management program is an energy study of the building and facilities. It begins with a step-by-step analysis of the building's energy-use factors and costs, such as insulation values, lighting levels, boiler efficiencies, and fuel expenditures. When the study has been completed, it gives the energy consultant a fair idea of the savings and the energy conservation opportunities (ECOs). The duration of such a study usually depends on the size and complexity of the building as well as the conditions of its energy systems.

The fees of the consultants are ordinarily set as a percentage of the total cost of the construction project. However, that system doesn't work for most energy studies, because the total cost of an energy management program cannot be determined until after the initial study has been performed. The percentage fee for preliminary studies has thus been replaced by a flat fee based on the time and effort required for a particular study.

Many owners of buildings are reluctant to carry out energy studies in their own facilities, especially if it requires significant expenditures. They fear an interruption of business that may bring about changes in their daily schedule as well as a decline in the comfort of their buildings. This is an erroneous perception because these programs do not result in noticeable changes in comfort levels of the affected buildings. In addition, investing in these programs will generate a higher rate of return than any other investment the owner could make [2].

Consider, for example, if a bank invested $80,000 in a variety of energy conservation measures, as a result of which the annual expenditure on fuel and other utilities dropped from $1.2 million to $1 million. This represents a payback period of 4 years, which is not at all unusual. It is because of such potential savings that energy management program should be looked at as positive investment opportunities and not as hindrances to business.

CHAPTER 2

BACKGROUND

2.1 What is an Energy Audit?

An energy audit can be defined as a process to evaluate where a building or plant uses energy, and identify opportunities to reduce consumption. Different audits have different emphases, depending on the facility being audited. A building energy audit focuses more on the building envelope, lighting, heating, and ventilation requirements. Depending on the complexity of energy audits, there are three main types of energy audits, which are described as follows.

The Walk through Audit **-** As the name implies, this type of audit is a visual inspection of the energy systems in the building facility. Typically it includes an evaluation of energy consumption data and patterns. It also involves an analysis of the averages or benchmarks for similar facilities. This type of audit is less costly but effective, as it gives a representative idea for more detailed audits if there are reasonable amounts of energy savings to be realized.

Standard Audit - In this type of audit, there is a more detailed review and analysis of equipment, systems, and operational characteristics. Standard energy engineering calculations are used to analyze efficiencies and calculate energy and cost savings based on improvements and in each system. The standard audit also includes an economic analysis of recommended conservation measures.

Computer Simulation - This level-three audit includes more detail regarding energy use by function and a more comprehensive evaluation of energy-use patterns. Computer simulation software for building systems is developed for this purpose. Because of the time involved in collecting detailed equipment information and operational data, and in setting up an accurate computer model, this is the most expensive energy audit.

Table 1: Comparison of Different Types of Energy Audits

	Walk Through Audit	**Standard Audit**	**Computer Simulation**
Level of inspection	Visual Inspection	Detailed inspection and analysis of equipment, systems, and operational characteristics	More detailed inspection of energy use by function and a comprehensive evaluation of energy use patterns
Cost	Least costly	Costly than walk-through audit	Most expensive of all audits
Energy savings	Standard energy engineering calculations are used to analyze efficiencies	Standard energy engineering calculations are used to analyze efficiencies	A computer simulation of building systems is developed that will predict year-round energy changes
Duration of audit	Less time	Comparatively more time	It is the most time consuming process among all audits

2.2 Procedure for Conducting an Energy Audit

Once the level of audit to be performed is decided, information regarding the structural and mechanical components that affect building energy use and the operational characteristics of the facility should be collected. The audit process can be divided into three phases, namely pre-site work, the site visit, and post-site work.

2.2.1 Pre-Site Work

Pre-site work is important in getting to know the basic aspects of the building. Pre-site work helps to develop a list of issues to be addressed with building personnel. It also reduces the time required to complete the on-site survey.

The energy data for the previous two years should be collected and reviewed, then tabulated and plotted. Seasonal patterns, unusual spikes, and accuracy of billings should be checked. This makes it easier to identify areas with the greatest savings potential.
All of the mechanical, electrical, and architectural drawings for the original building, as well as for any remodeling work that may have been done, should be obtained. Simple floor plans of the buildings should be drawn and several copies should be made for note taking during the actual site visit. Audit data forms should be used to collect, organize, and document all pertinent building and equipment data. The gross square footage for each building to be visited should be calculated. A building profile narrative that includes age, occupancy, description, and existing conditions of architectural, mechanical, and electrical systems should be developed and major energy consuming systems should be noted. The energy use index (EUI) in Btu/sqft/year should be calculated and then

compared with EUIs of similar building types. The EUI can be calculated by converting the annual consumption of all fuels to BTUs and then dividing by the gross square footage of the building. A comparatively low EUI indicates less potential for large energy savings.

While completing the pre-site review, areas of particular interest should be noted and questions that may address lighting type and controls, HVAC zone controls, or roofing type should be written. Preliminary data obtained should be discussed with the building manager or operator and they should be asked if they are interested in particular conservation projects or planning changes to the buildings or its systems. A list of potential energy conservation measures (ECMs) should be developed.

2.2.2 Site Visit

The site visit is spent inspecting actual systems and answering questions from the pre-site review. The amount of time required for each building varies depending on the pre-site information collected, the complexity of the building and systems, and the need for testing of equipment. Some basic audit tools include notebook, calculator, flashlight, tape measure, pocket thermometer, stroboscope, light meter, and camera. The auditor should make sure to take photographs as he or she walks through the building.

2.2.3 Post-Site Work

Immediately after the audit, notes should be renewed and clarified. ECM and operation & maintenance (O&M) lists that are proposed should be revised. Preliminary research on potential conservation measures should be conducted, and conditions that require further evaluation by a specialist must be noted. Photographs should be processed and imported on a computer, and notes should be added to each photo as required. All documents should be organized in one folder, as energy auditing can be an on-going process. Files should be dated, and revisions should be marked. This makes it easy to add or update things for future use.

2.3 Audit Report

Based on the results of the preliminary audits, some sectors can be selected for detailed audits. The audits will contain comprehensive measurements at the plant facilities and units selected. Each audit will consist of the following tasks:

- Elaboration and discussion of audit methodology;
- Selection of plants items to be audited;
- Gathering more detailed energy and production data, if available;
- Comprehensive measurements at selected plants items;
- Data analysis and calculations;
- Elaboration of energy and material balances for the audited plant items;
- Investigation of existing energy management structures;
- Recommendation of feasible energy efficiency measures;
- Financial analysis of recommended measures, including cost benefit calculation;
- Ranking of measures and elaboration of an energy saving action plant;
- Reporting; and
- Presentation to plant management.

2.4 The Energy Audit Report

The next step in the energy audit process is to prepare a report, detailing the final results and recommendations. The length and detail of this report varies depending on the type of facility audited. A residential audit results in a computer printout from the utility. An industrial audit is more likely to have a detailed explanation of the ECMs and cost-benefit analyses. The report should begin with an executive summary that provides the owners/managers of the audited facility with a brief synopsis of the total savings available and the highlights of each ECO. The report should then describe the facility that has been audited and provide information on the operation of the facility that relates to its energy costs. The energy bills including electricity, natural gas, and water should be presented, with tables and plots showing the costs and consumption. A summary list of ECM that meet the financial criteria should be established. A list of operation and maintenance measures should be made based on the site visit. The executive summary should be tailored to non-technical personnel, and technical data should be minimized. Support technical data should be added as an appendix. A client who understands the report is more likely to implement the recommended ECOs.

2.5 Energy Audit Successes and Case Studies

Some of the case studies and their successes are listed as follows [5]:

- In 2001, state office buildings in California cut energy use by an average of 22%, including a 26% reduction in one month.

- California's Department of General Services benchmarked 35 buildings in 2001. One building was awarded the Energy Star rating in 2001, and two more earned the Energy Star rating in 2002.
- A new state complex in Sacramento, the Capitol Area East End, is expected to save $429,000 annually in energy costs as a result of its sustainable and energy-efficient design and construction.
- The strongest energy efficiency building standards in the country went into effect in California in 2001. In five years, energy savings from these standards are expected to reach 1,000 MW (947 817.12 Btu/s) a year — enough to power an estimated 750,000 homes.
- Many cities, counties, and special districts in California reduced energy use in their facilities by at least 15% and empowered their communities to use energy more wisely. The City of Poway, for instance, retrofitted traffic lights with energy-efficient light emitting diodes (LEDs), for a 71% energy cost reduction, and built a high-efficiency living community for senior citizens.
- In June 2000, the Elihu Harris State Office Building's (Oakland) average peak kilowatt demand was 1,416 kilowatt (KW) or 1342.11 Btu/s. Between June 2000 and June 2001, the facility implemented conservation improvements amounting to 387 KW (366.81 Btu/s) reductions in lighting, HVAC and plug-in loads. In addition to the conservation improvements already implemented, the peak load reduction (PLR) plan identified an opportunity for 346 KW (327.94 Btu/s) additional curtailments, for a total 733 peak reduction of KW (694.75 Btu/s)by June 2001.

- Since 1990, the City of Sacramento has reduced its electrical load by more than 1.5 MW (1421.73 Btu/s). Between 1992 and 2000 the city completed 23 energy retrofit projects, such as installing energy-efficient lighting, HVAC equipment, and LED lamps in traffic signals. Sacramento's extensive program has resulted in a cumulative 38% reduction in electrical energy usage, more than $440,000 in annual energy savings, $535,000 in Sacramento Municipal Utility District (SMUD) rebates, and more than 6,400,000 kWh (21,83,77,06,464.85 Btu) in energy savings (or an approximately 6.1% reduction annually). In response to the 2001 energy crisis, the city council developed a plan to reduce energy use by another 7% and pledged to curtail 1.8 MW (1706.08 Btu/s) at SMUD's request. With the completion of projects scheduled for 2001 and 2002, total reductions are expected to exceed 2 MW (1895.63 Btu/s), which is enough electricity to power 2,000 homes. Sacramento beat its goal with a 9% energy reduction citywide, with conservation accounting for 72% of the savings and efficiency projects for 38%.

These were some of the case studies performed and their successes. A detailed case study report is listed in Appendix A.

CHAPTER 3

ENERGY USE AND CONSERVATION

3.1 Energy in Buildings

The role of the energy manager is to reduce the volume of fuel consumed or wasted per annum in a building or complex of buildings, thus saving the owner's money while conserving the nation's fuel resources. In this approach, it is necessary to know which part of the building uses what percent of the building's total energy. Due to the diverse nature of buildings, each building has to be approached by a different methodology, depending on such factors as climate, building orientation, and building purpose. Studies have revealed certain recurring patterns of energy consumption based on structure and climate. It is found that heating generally consumes most of the energy used in the majority of buildings.

Since all buildings are dissimilar, there is no set rule for determining which part of a building's comfort system accounts for the bulk of that system's energy demand. The seasonal combustion efficiency of typical burner-boiler units ranges from a high of 78 to a low of 30, with many factors bearing on its efficiency. The ranking of systems within building across the country according to energy use is as follows [2]:

1. Heating and ventilation; 2. Lighting; 3. Cooling and ventilation; 4. Equipment and machinery; 5. Domestic hot water

The relative magnitude of energy use by the HVAC and lighting systems varies according to climate, building design and construction, mode of operation, and efficiency of equipment. In climatic zones with mild winters, the seasonal cooling load may be heavier than the seasonal heating load and may consume more energy. In colder climates, heating usually consumes the most energy.

3.2 Principles of Energy Use in Buildings

The most important principle to remember while performing an energy study in existing buildings is that the various features and systems contributing to a building’s total annual energy demand are interrelated in significant ways. For example, a reduction in a building’s lighting level may affect not only the cooling load but also the demand on heating and humidity control equipment, in turn affecting the load demand on pumps, fans, boilers, and chillers. This principle should be kept in mind while reviewing other major principles of energy use.

3.2.1 Energy Loads

The energy requirements of the building are expressed as three loads i.e., the building load, the distribution load, and the primary equipment load.

Building load: It is the amount of energy in BTUs or kilowatts required to maintain the indoor environment at desired levels, if the building’s electrical and mechanical systems are 100% efficient. The size of the building load is governed by several factors, such as location and orientation, environment maintained in the building, heat loss and gain through building shell and function and period of occupancy [2, 3].

Distribution load: This type of load mainly arises in pumps and fans and their associated piping and duct work. They are also called parasitic loads, since they do not contribute directly to the comfort and other requirements of the building occupants. The size of the distribution load mainly affects the energy consumed by the primary heating and cooling equipment.

Primary equipment load: This type of load is primarily from energy conversion equipment, such as boilers and chillers. Surplus load is a result of their inefficiency, which results from the design of the equipment, the way it is maintained, and the number of times it is turned on and off. Poor maintenance also reduces efficiency. Soot and scale reduce the efficiency of heat transfer in a boiler as dust on lamps reduces their light output. Frequent variations in demand will also reduce equipment efficiency [2].

3.2.2 Analysis of Loads on a Seasonal Basis

The primary equipment load is strongly affected by daily and seasonal variations in the schedules and functions of the building. For example, once a furnace is fired and burning, it may reach 90% efficiency, but that efficiency will decline by 10 to 30% when the furnace is monitored on a seasonal basis, due to stack losses between firing periods. There will be a similar decline in the seasonal efficiency of most other units of primary equipment and therefore it is important that a yearly analysis of a building's energy consumption be conducted, thus accounting for seasonal variations.

3.2.3 Cumulative Nature of Load Reductions

Due to interrelationships between several factors determining a building's energy demand, the energy professional generally wants to pursue a standard sequence of operations in implementing fuel conservation measures:

- Effect operational ECO's;
- Reduce the building loads;
- Reduce distribution losses from the central plant to the terminal units; and
- Improve the efficiency of primary conservation equipment.

3.3 Energy Use Index

Each energy type is converted to a common unit (BTUs) for comparison and calculation of the total energy consumed. The EUI is the most common means of expressing the total energy consumption for each building. The EUI is expressed in BTU/square foot/year and can be used to compare energy consumption relative to building types or to track consumption from year to year in the same building. The EUI is calculated by converting annual consumption of all fuels to BTU and then dividing by the gross square footage of the building. A comparatively low EUI indicates less potential for large energy savings.

3.4 Energy Conservation Measures

Once the initial survey has been conducted and all of the necessary data is obtained, the auditor uses this information to develop an initial list of potential energy conservation measures and prioritize on-site audit activities. The most common ECMs found in existing buildings are listed in the following sections:

3.4.1 Building operation

An enormous amount of energy is wasted because building equipment is operated improperly or unnecessarily. The amount of heat supplied to or extracted in order to maintain a comfortable indoor environment is directly proportional to the difference in temperature and humidity between the indoor and outdoor environments. Consequently, one should lower the heating and raise the cooling temperature set points and/or lower the humidification set points and raise the dehumidification set points to minimize the space conditioning requirements wherever possible. When the building is not occupied, the building systems should off their operation reduced to a minimum.

Depending on building operations, the operating hours of the systems like the HVAC systems, water heating systems, lighting systems, escalators and elevators, and other equipment and machinery may be curtailed during unoccupied periods. Care should be taken that any reduction in equipment operating hours has no adverse impact on building operations and systems, safety or security.

3.4.2 Lighting System

Energy consumption for all lighting in the United States is estimated to be 8.2 quads, or about 22% of total electricity generated annually [6]. The pie chart in Figure 1 provides a breakdown by end-use sector of the energy consumed in lighting our homes, offices and other installations. More than half of the energy is consumed in the commercial sector, where lighting coincides with peak electrical demand and contributes to a building's internal heat generation, increasing air-conditioning load.

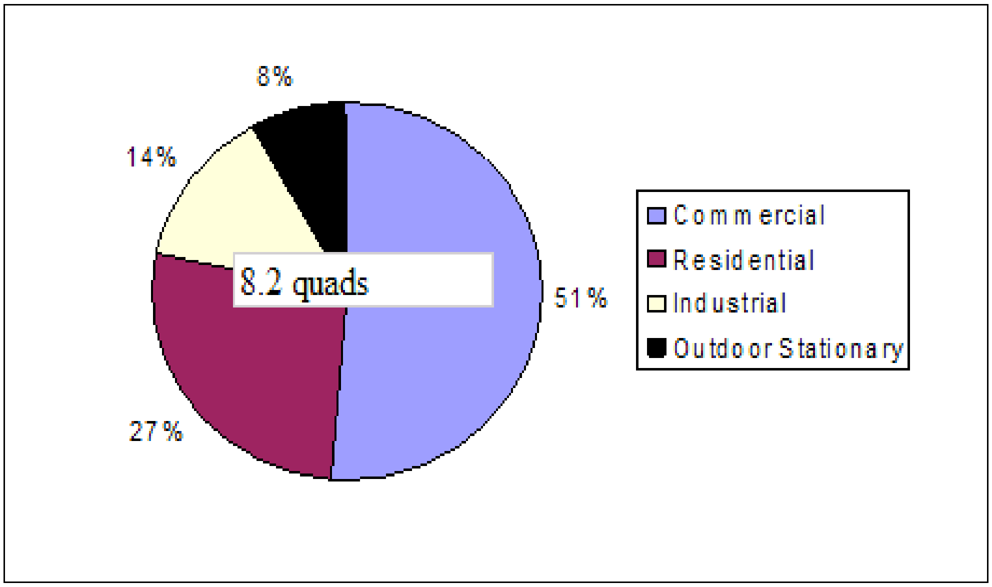

Figure 1: Total U.S. Primary Energy Consumption for Electricity for Lighting by Sector, 2001

The energy use of a lighting system can be reduced in two ways: reduce the lighting system's input wattage (W or kWh) or reduce its hours of operation. Input wattage can be reduced by replacing lamps and ballasts with more energy efficient counterparts or by removing lamps and ballasts outright. The hours of operation can be reduced using sophisticated controls. Lighting systems convert only a fraction of their electrical input into useful light output. Much of the rest is released as heat. Therefore, any upgrade of the lighting system that reduces input wattage reduces the amount of heat that must be removed by the air cooling system. This results in air cooling energy savings during the operation of the building. In new construction, an energy-efficient lighting design can result in significant savings in the installation cost of cooling systems.

Fluorescent lamps are more efficient than incandescent lamps. All fixtures for fluorescent lamps installed indoors must use Class P ballast that disconnects the ballast in the event it begins to overheat; high ballast operating temperatures can shorten ballast life [7]. Linear fluorescent lamps often are less expensive than compact fluorescent lamps. They also produce more light, are easier to dim, and last longer. Cold cathode fluorescent lamps are one of the latest technological advances in fluorescent technology. The "cold" in cold cathode means that there is no heating filament in the lamp to heat up the gas, which makes them more efficient. Also, since there is no filament to break, they are ideal for use in rough service environments where a regular lamp may fail. They are often used as backlights in LCD monitors or in exit signs. High-intensity discharge lamps are typically used when high levels of light are required over large areas and when energy efficiency and/or long life are desired. These areas include gymnasiums, large public areas, warehouses, outdoor activity areas, roadways, parking lots, and pathways. Occupant sensors are used in reducing costs, increasing control intelligence, improving the ability to detect minor motion, and increasing adjustment capabilities. Low-pressure sodium lamps are used where color rendition is not important but energy efficiency is.

They are commonly used outdoors, e.g., roadways, parking lots, and pathways. Light emitting diodes can be used for exit signs as they are more energy efficient than conventional incandescent fixtures. Electronic ballasts are more energy efficient than magnetic ballasts. These electronic ballasts experience half the power loss of magnetic ballasts. They are also quieter, lighter, and virtually eliminate lamp flicker. [7]. Lamps in multiple lamp fixtures should be disconnected or removed. Task lighting should be used wherever needed. Blinds and shades should be opened and lights should be turned off in unoccupied areas or in spaces with sufficient natural lighting. Janitorial cleaning schedules should be adjusted to reduce total lighting and equipment energy use. Moving cleaning schedules to business hours can reduce overall energy cost. Teamwork should be used to reduce lighting loads. Cleaning staff can work in teams (instead of different areas simultaneously) to reduce lighting usage. This can save up to 20% in lighting energy [8]. Fixtures that have dimmers, which allow one to manually adjust the intensity of light in a room, should be installed. Dimmers can be used with incandescent lights, including low-voltage systems, but only with new screw-based dimmable fluorescent bulbs. Other fluorescent lights must have their own dimmable ballasts. Motion sensors must be installed outdoors. Timers and sensors should be used on outdoor lights to avoid leaving the lights on during nighttime hours. Incandescent light bulbs must be replaced with compact fluorescent lamps (CFLs) wherever appropriate. CFLs use at least 66% less energy and last an average of 10 times longer [2, 3, 8]. T12s and magnetic ballasts should be converted to T8 lamps and electronic ballasts. T8 lamps produce more light per watt of energy input than T12s and can reduce energy by 40% [8].

Occupancy sensors should be installed in the proper locations to automatically turn off lighting when no one is present and back on someone enters. Sensors in rooms with high traffic e.g., break rooms, restrooms, and conference rooms should be used to reduce lighting costs by up to 40%. The sensor should not be installed behind a coat rack, door, or book case. It must be able to "see" the motion of an occupant approaching an unlit area to turn on the light before or as occupant enters [2, 5, 8]. Hallway and security lighting should be retrofitted. Hallway and non-public security lighting must be converted to energy saving 25-watt T12 bulbs [3, 8]. Restroom fans should be rewired to operate only when lights are turned on and the restroom is occupied. Exit signs with LEDs should be installed. A new LED exit sign fixture will save about 90% over an incandescent bulb's operating costs. Standard fluorescents should be replaced with T8s and matched electronic ballasts. This provides an estimated savings in electricity operating costs of 35 to 45%. Energy management system (EMS) technology should be installed to control lighting systems automatically. Energy savings can range from 10 to 15% [2, 3, 8].

3.4.3 HVAC Systems

HVAC accounts for 40 to 60% of the energy used in U.S. commercial and residential buildings [3]. This represents an opportunity for energy savings using proven technologies and design concepts. An HVAC system can account for up to 30% of a building’s energy usage [5]. The HVAC systems in the building are made up of energy conversion equipment (which transforms electrical or chemical energy to thermal energy) and distribution and ventilation systems (which transport the thermal energy and supply fresh outdoor air to the conditioned space).

Simple ways to minimize on the operational cost are given as follows. The system should be turned off and an experiment should be conducted to determine how long it takes for the building space to heat up or cool down. The thermostat should be timed to turn on shortly before occupants arrive and to shut off one half-hour before they leave, so that the space is temperate only when it's full of employees. Outside air should be drawn into the building, as it works as a natural and efficient coolant, especially at night. Warm air can be flushed out by ventilating the cool side of the building or by operating attic vents and fans on that side. Air duct registers and vents should be adjusted to manage the flow of tempered air and increase the employees' overall comfort level. Exhaust fans should be used sparingly. Energy and money can be saved by using sensors or timers to ensure that the exhaust fans run only when needed.

The HVAC system should be kept clean**.** The efficiency of the system can be improved by careful maintenance. Filters have to be replaced periodically. The ASHRAE developed two HVAC industry standards that address the efficiency issue. ASHRAE 52.1 standard measures are as follows:

- Pressure drop: How the filter affects air flow and energy costs. A low-pressure drop typically translates into higher energy efficiency. A high-pressure drop means reduced air flow to the HVAC unit. This requires more energy to operate the unit;
- Arrestance: The amount of synthetic dust a filter is able to capture;

- Dust-spot efficiency: A measure of the ability of the filter to remove atmospheric dust from test air; and
- Dust-holding capacity: The amount of dust a filter can hold until a specified pressure drop is reached. Higher capacity means a longer filter life. When evaluating dust-holding capacity, it's important to compare dust-holding capacities between filters at the same final pressure drops to make accurate comparisons of projected filter life. The ASHRAE 52.2 standard measures the fractional particle size efficiency (PSE) of an HVAC filter. This indicates the filter's ability to remove airborne particles of differing sizes between 0.3 and 10 microns in diameter. A MERV (Minimum Efficiency Reporting Rating) is assigned to the filter media depending on the PSE in three different particle size ranges (0.3 to one micrometer, one to three micrometers, and three to 10 micrometers). MERV is a numerical system of rating filters based on minimum particle size efficiency. A rating of one is least efficient, while a rating of 16 is most efficient [9]. Proper filter maintenance is important to keeping HVAC ductwork clean. Filters should be changed if they become wet, microbial growth on the filter media is visible, or when filters collapse or become damaged to the extent that air bypasses the media.

The thermostat in the workspace should be set to 78°F during work hours, and 85°F when the space is unoccupied. The energy savings can be as much as 2% of the air conditioning costs for each one-degree increase in the temperature. If all businesses in California set their thermostats to a higher temperature, the state could save 770 MW

(729,819.18 Btu/s) for every 2^{o}F increase. Seasonal adjustments should be made**.** Water pumps should be turned off in hot water heating systems in mild weather. Boilers - Whether gas or oil, ENERGY STAR qualified boilers should be used, as they use about 10% less energy than a standard boiler. ENERGY STAR qualified boilers have an annual fuel utilization efficiency (AFUE) rating of 85 or greater [5, 8]. Point-of-use heaters should be used wherever possible. These water heaters are compact heating units that provide hot water as it is needed and do not store hot water like traditional tank-type water heaters. When a hot water tap is turned on, water enters the tankless water heater. A sensor detects the water flow, and activates an electric or gas heating device, which quickly raises the water temperature to a present level. When the water flow stops, the heating element shuts off. Unlike traditional storage tank water heaters, these point of contact heaters do not store a reservoir of hot water. As a result, standby losses are reduced, which makes them an energy efficient alternative to traditional water heating. These units can reduce water heating bills by 10 to 20%. They are also easy to retrofit. The air conditioning cost can be reduced by replacing a 1970s-era central air conditioning with a SEER of 6 with a new unit having a SEER of 12. A high efficiency packaged HVAC system should be installed. These can use up to 40% less energy than systems that just meet minimum standards. A system with high SEER (Seasonal Energy Efficiency Ratio) or, on larger units, EER (Energy Efficiency Ratio), should be used. High-efficiency air conditioning equipment should be specified when the system needs to be replaced, and 25 to 35% of one's energy costs can be saved on the investment annually [2, 3]. Workplace schedules should be adjusted to reduce energy use during the "peak" hours when there is the most demand for electricity, typically noon to 7 p.m. Power strips should be turned off, thereby turning off computer scanners, printers, and other devices that are plugged into the strips, after shutting down the computers. Electronic products and appliances without built-in clocks or timers should be selected. The displays consume about a half watt, but the power supply in the appliance converts 120 volts of alternating current to low-voltage direct current for the clock or timer. This is very inefficient and consumes 20 to 100 watts/hour (68 to 341 Btu) per day. This is enough to run a CFL continuously for 10 hours. Solar entry and air conditioning loss during the summer should be prevented by the use of shades and blinds. Outside doors should be closed to keep in cooler air [2, 3, 5, 8].

3.4.4 HVAC Distribution Systems

HVAC distributing systems transport the heating and cooling fluids from the central plants e.g., chillers and boilers, to the conditioned space. The system is made up of a network of pipes, ducts, fans, and pumps. Energy is required to operate the fans and pumps that transport the working fluids. In addition, thermal energy is lost from the distribution systems, reducing heating and cooling capacity. Energy can be saved by preventing losses during transport throughout the distribution system.

3.4.5 Building Envelope

The building envelope can be defined as the exterior plus the semi-exterior portions of a building. For the purpose of determining building envelope requirements, the classifications are defined as building envelope, (exterior) which includes the elements of the building that separate conditioned spaces from the exterior, and building envelope, (semi-exterior) which includes the elements of a building that separate conditioned space from the unconditioned space or that enclose semi-heated spaces through which thermal energy may be transferred to or from the exterior, or to and from unconditioned spaces, or to and from conditioned spaces [10].

The building envelope includes everything that separates the interior of a building from the outdoor environment, including the windows, walls, foundation, basement slab, ceiling, roof, and insulation. Energy is saved when the heat exchange between the building and the outside environment is reduced and solar and internal heat gains are controlled. The area of U.S. roofs covered by vegetation has increased more than 80% in the past year, according to Green Roofs for Healthy Cities (GRHC), a trade association. So-called green roofs are rooftop gardens that reduce storm water runoff, insulate against heat and sound, increase energy savings, and improve air quality. They also reduce the urban heat-island effect, which is caused by dark urban roofs, pavement, and other infrastructure absorbing the sun's heat. The GRHC recently completed its first survey of its members to gauge the growth of green roofs, finding that in 2005, green roofs covered at least 2.5 million square feet of roof space in North America, up from 1.3 million square feet in 2004. Cities that used the largest area of green roofs in 2005 are Chicago, Illinois; Washington, D.C.; and Suitland, Maryland. Toronto may catch up to these other cities quickly, since the city council recently passed a policy that requires green roofs to be incorporated into city buildings and provides financial incentives for green roofs [11].

Using high-efficiency building-envelope components not only reduces energy use, but also allows smaller heating and cooling systems to be installed, generating additional savings. While the opportunities can be found almost anywhere in the building envelope, the most significant savings can be found in roofs and windows. The use of the following materials in building envelope can save energy. Energy efficient windows marked by the Energy Star label should be used. More information is provided by the National Fenestration Rating Council Label, including solar heat gain coefficient (SHGC), U-value, and visible transmittance. High-tech efficiency options include windows with argon between the window panes and low-emissive coatings [12]. Different types of buildings require different kinds of insulation according to the location and climatic conditions. Usually the amount of insulation is calculated using the R-values per inch. When building new walls and ceilings, advanced framing techniques help to achieve energy efficiency. A numerous of alternative materials are now being used to construct buildings. Many have energy efficiency as well as environmental benefits. These materials include adobe (clay or straw), straw bales, rammed earth and tires, and other recycled materials. White or reflective roofing helps reflect heat and keep buildings cool. Look for the ENERGY STAR label on roofing products. A white roof surface reduces the load imposed on the building’s cooling system by reflecting much of the solar energy striking it. In contrast to a dark roof surface, a white roof surface will reflect between 70 and 80 % of incoming solar energy. In most cases, the temperature of a reflective roof will remain between 20 and 25 degrees higher than the ambient temperature. Because the surface temperature of the reflective roof is lower than it would be with a dark roof, the heat gain from the roof will be reduced, cutting air-conditioning requirements and energy costs. A side benefit of the reduced roof temperatures is a longer service life for the roof, as cooler temperatures slow the breakdown of many roofing materials [12]. Leakage of outside air into a building can be prevented with air infiltration barriers, also called air retarders.

3.4.6 Power Systems

The inefficient operation of power systems arises primarily from low power factors, which can be improved with power factor correction devices and high-efficiency motors. Energy can be saved by replacing existing motors with high-efficiency motors or by installing variable speed motors. The peak power demand can be reduced by load-shedding, cogeneration, or cool storage systems that produce cold water or ice during off-peak hours. Evaluation of power management measures requires a determination of the building demand profile. Readings obtained at 15 minute intervals should be taken for several weeks with a recording meter.

3.4.7 Water Heating Systems

Generally, the heating of water consumes less energy than space conditioning and lighting. Water heating energy can be conserved by reducing load requirements, reducing distribution loses, and improving the efficiency of the water heating systems.

The standard form of water heating in the United States, the tank water heater, uses less energy when insulation is added and the water temperature is reduced. Heat pumps are more energy efficient than standard electric or gas water heaters. Any hot water that goes down the drain carries energy away with it. Drain water heat recovery systems save energy by using the heat in drains to preheat water coming into the water heater, thereby reducing energy consumption as well as peak power demand.

CHAPTER 4

SURVEY INSTRUMENTATION

To conduct an energy audit, energy use and losses need to be clarified. This chapter focuses mainly on the instruments that can help in an energy audit survey.

4.1 Light Meter

A light meter is used to measure the amount of light in foot candles that falls on a surface. It consists of a photo cell that senses the light output and converts it to electrical impulses, which are calibrated as lux. In doing such a lighting survey, it is important to express light intensity for selecting lamps and to lay out the overall lighting configuration. It is therefore useful to define the following terms:

4.1.1 Lumens

Lumen is the unit (amount) of total light output from a light source. If a lamp or fixture were surrounded by a transparent bubble, the total rate of light flow through the bubble is measured in lumens. Lumens indicate a rate of energy flow, corresponding to a power unit, such as watts or horsepower. Typical indoor lamps have light outputs ranging from 50 to 10,000 lumens.

4.1.2 Foot candles and Lux

Foot candles (Fc) and lux are units that indicate the density of light that falls on a surface which is measured by a light meter. For example, average indoor lighting ranges from 100 to 1,000 lux, and average outdoor sunlight is about 50,000 lux. The foot candle is an older unit of measurement based on English measurements. It is equal to one lumen per square foot. It is being replaced by lux, a metric unit equal to one lumen per square meter. One foot candle equals 10.76 lux [13].

The survey instrument used for the energy audit was a heavy duty light meter from EXTECH instruments which is shown in Figure 2.

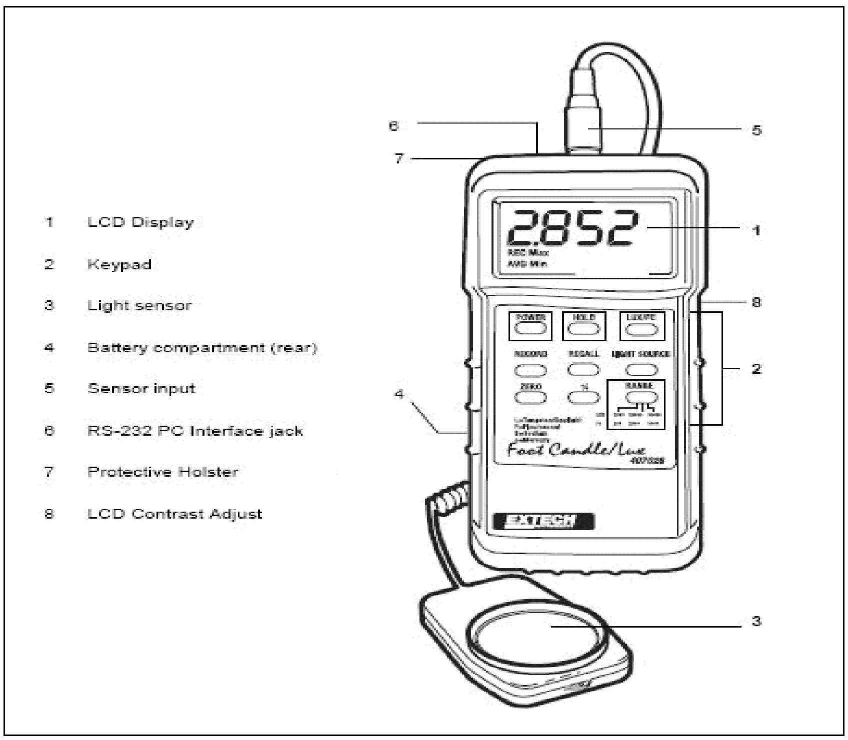

Figure 2: Extech Light Meter [14]

Note : Adapted from “User’s Guide Heavy Duty Meter Model 407026” by Extech Instruments, 2004, p.4, Copyright 2004 by Extech Instruments Corporation. Adapted with permission.

4.2 Data Loggers

A data logger is an electronic instrument that records measurements e.g., temperature, relative humidity, light intensity, carbon dioxide (CO_2), voltage, pressure, and events over time. Typically, data loggers are small, battery-powered devices that are equipped with a microprocessor, data storage, and a sensor. Most data loggers use turn key software on a personal computer to initiate the logger and view the collected data. In our energy audit, the data logger was used to measure the amount of CO_2 present in a room. The Extech heavy duty data logger used in the energy audit is shown in Figure 3.

- Carbon dioxide is exhaled by building occupants and therefore can be used to provide a more accurate accounting of occupancy periods and patterns than that mentioned by building personnel. Outdoor ambient concentrations of CO_2 are typically in the range of 250 to 350 parts per million (ppm). By recording CO_2 levels over time, one can use concentrations above ambient conditions to determine when the area is actually occupied. Carbon dioxide can also be used to evaluate ventilation rates in the area being monitored. The concentration of CO_2 can be used to determine the ventilation rate in cubic feet per minute and compare it to the ventilation standards (ASHRAE 62-1999). The levels of CO_2 in the air and potential health problems are summarized as follows. The ambient outdoor air level is within the range of 250 – 350 ppm. The outdoor ambient level typically found in occupied spaces with adequate air exchange is within the range of 350 – 1,000 ppm. The level associated with complaints of drowsiness and poor air ventilation is within the range of 1,000 – 2,000 ppm. The level associated with is within the range of headaches, sleepiness, and stagnant, stale, stuffy air, poor concentration, loss of attention, increased heart rate, and slight nausea is within the range of 2,000 – 5,000 ppm. With levels of CO_2 more than 5,000 ppm, there may be serious oxygen deprivation resulting in permanent brain damage, coma, and even death [15].

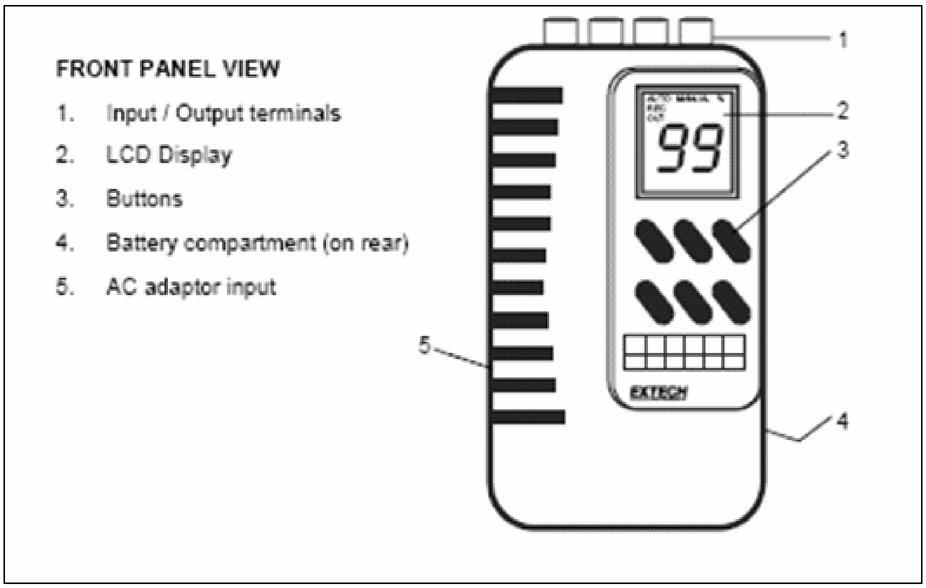

Figure 3: Data logger [16]

Note : Adapted from “User’s Guide Heavy Duty Data Logger Module Model 380340” by Extech Instruments, 2004, p.3, Copyright 2004 by Extech Instruments Corporation. Adapted with permission.

4.3 Infrared Thermometers

An infrared thermometer measures the surface temperature of an object by sensing its emitted energy, reflected energy, and transmitted energy. This information is collected by the sensor, directed into a detector, and translated by a microprocessor into a temperature reading that is displayed on the unit. It can be used to check for heat leaks through walls, windows, or ducts. These types of non-contact thermometers are compact, lightweight, and easy to use. They can safely measure hot, hazardous, or hard-to-reach materials without touching, contaminating, or damaging the material's surface.

The important thing to keep in mind while using this thermometer is the temperature range of the intended use and the distance from the material. Temperature range is usually in the range of -25 to 1400^{o}F. Optics is given in a ratio, such as 6:1 or 10:1, indicating the distance where a spot size will be 1 foot in diameter. The infrared thermometer used in the survey is shown in Figure 4.

Figure 4: Infrared Thermometer [17]

Note : Adapted from "Operating Manual InfraPro 3 Non-Contact Thermometer" by Oakton Instruments, 2004, p.5, Copyright 2004 by Oakton Instruments. Adapted with permission.

4.4 Anemometer

The air velocity gauge, or thermo-anemometer, is useful for detecting air flow within buildings and for determining whether ventilation ducts are properly balanced. Flowing air turns the plastic impeller, which provides a reading of how quickly the air is flowing. A detector near the end of the gauge also measures the air temperature. The model 45158 mini hydro thermo-anemometer from Extech Instruments Company, Inc. used for the energy audit is shown in Figure 5.

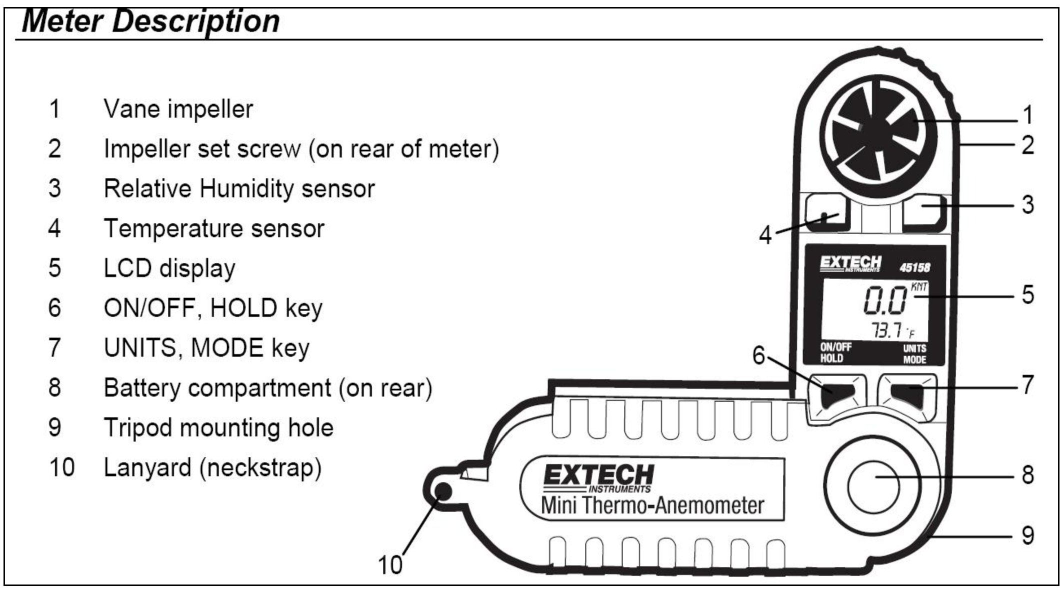

Figure 5: Thermo-Anemometer [18]

Note : Adapted from "User's Guide Mini Hygro Thermo-Anemometer Model 45158" by Extech Instruments, 2003, p.2, Copyright 2003 by Extech Instruments Corporation. Adapted with permission.

4.5 Flicker Checker

The Flicker Checker determines whether fluorescent lights to have magnetic or electronic ballasts. It does so using the principle of a stroboscopic effect to detect the light's cycle speed, showing a pattern if the ballast is magnetic and a blur if the ballast is electronic. The Flicker Checker manufactured by Sylvania used in the energy audit is shown in Figure 6.

Fluorescent lights operated by magnetic ballasts turn off and on 120 times per second. While this flickering is not usually discernable to the human eye, it does have a subliminal impact on the human brain and can cause varying levels of disorientation, headaches, and nausea. Fluorescent lights operated by an electronic ballast cycle off and on thousands of times per second. This faster cycle rate of lights with electronic ballasts does not cause a visual or subliminal effect on people.

Figure 6: Flicker Checker

4.6 Digital Stroboscope

The digital stroboscope is a highly stable instrument used to measure non-contact rpm, and to inspect and observe moving parts by freezing or slowing down the action.

4.6.1 Features

The setter changes the flashing rate. By pressing “x2”, the flashing rate will be doubled; by pressing “1/2”, the flashing rate will be halved. The digital stroboscope used in the energy audit is shown in Figure 7.

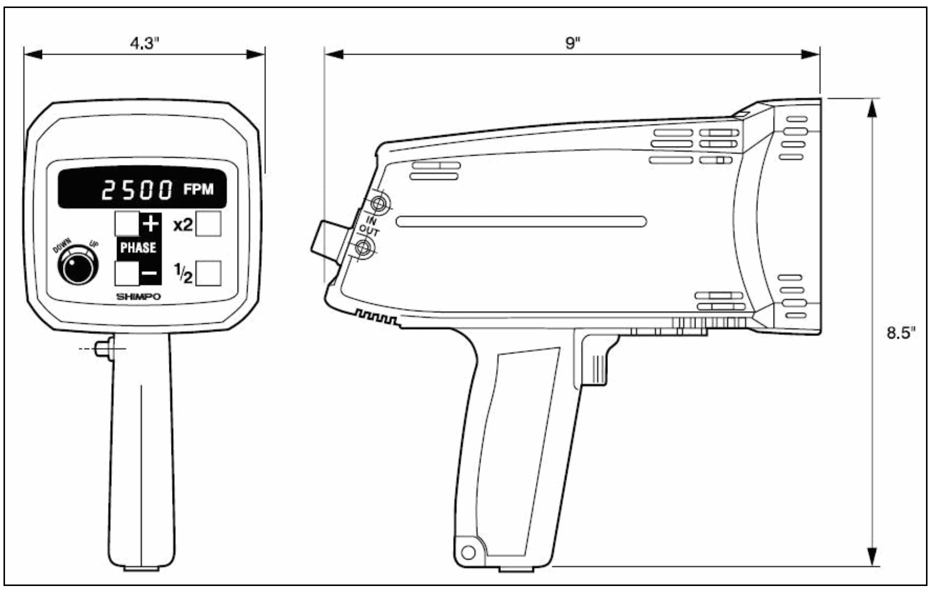

Figure 7: Digital Stroboscope [19]

Note : Adapted from “Instruction Manual Digital Stroboscope Model DT-725” by Shimpo Instruments, 2004, p.4, Copyright 2004 by Shimpo Instruments. Adapted with permission.

4.7 Clamp Meter

A clamp meter is a type of ammeter that measures AC current without the need to disturb the wiring through which the current is flowing. The clamp meter used in the energy audit is shown in Figure 8. In order to use a clamp meter, the probe or clamp is opened to allow insertion of the wiring and then closed to allow the measurement. If more than one conductor were to be passed through, the measurement would be a vector sum of the currents flowing in the conductors and could be very misleading, depending on the phase relationship of the currents. In particular, if the clamp were to be closed around a main extension or similar cord, no current would be measured at all, as the current flowing in one direction would cancel that flowing in the other direction.

1. Current sense jaw
 (shown with conductor inside jaw)
2. Measurement Trigger
3. Function switch
4. Data Hold key
5. Max Min key
6. One-touch DCA zero key
7. LCD Display
8. 40 segment bargraph display
9. Handstrap
10. Positive input terminal for V,W,HZ
11. COM terminal

Figure 8: Clamp meter [20]

Note : Adapted from “User’s Guide Mini Hygro Thermo-Anemometer Model 45158” by Extech Instruments, 2006, p.3, Copyright 2006 by Extech Instruments Corporation. Adapted with permission.

CHAPTER 5

THE ENERGY AUDIT

5.1 Objective and Location

The primary objective of this research was to conduct preliminary energy audits at different state facilties in Alabama and recommend energy conservation opportunities. The energy audit was conducted for the Alabama Department of Youth Services (Chalkville Campus), the Alabama State Capital Complex, Bryce Mental Health Hospital, and Fort Taylor Hardin Building under the guidance of Dr. Robert Peters and Dr. Jeff Perl. For this thesis, only two facilities were considered because Bryce Mental Health, Chalkville Campus and Fort Taylor Hardin are old facilties, and the Alabama State Capitol Complex is a comparatively newer one, extreme case data was considered. The audit was performed for 11 buildings at the Chalkville site on July 26, 2005, and 7 buildings for the Alabama State Capital complex on July 12-13, 2005 in Montgomery. The satellite photographs for the Chalkville Campus and the Alabama State Capitol Complex are shown in Figure 9 and Figure 10, respectively.

Figure 9: Chalkville Campus [Google Earth]

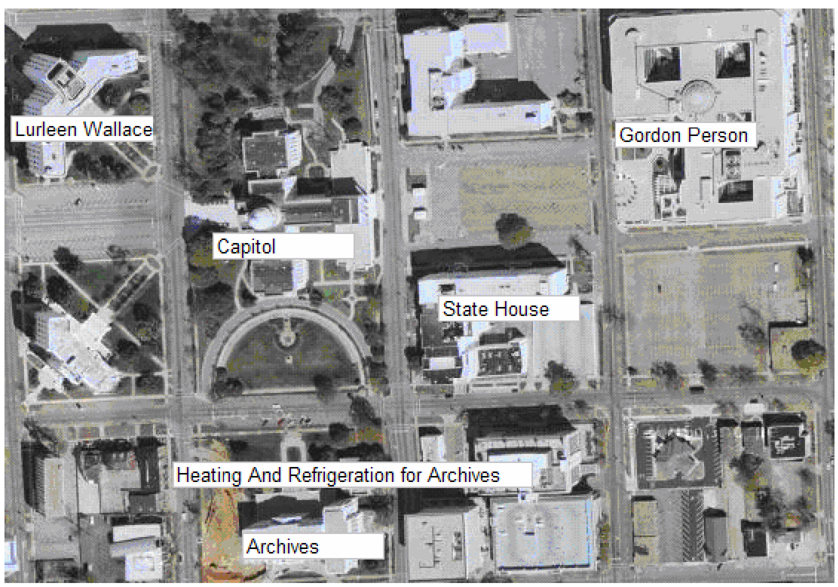

Figure 10: Alabama State Capitol Complex [Google Earth]

5.2 Procedure for Audit

Initial surveys were carried out by sending forms to the building managers of each facility. Appendix B provides a copy of the survey form sent to the various state agencies

The results from the survey are listed in Appendix C. A 1-page survey to assess building utility costs was developed and sent to the various agencies. On the day of the survey, a meeting was scheduled with the building managers to discuss areas that needed more attention. Plans for the facilities were provided and notes were made on the plan as the energy audit was carried out. A walk-through energy audit of each facility's mechanical and electrical spaces was conducted, and each building's overall lighting was observed. The photos from the energy audit are listed in Appendix D. The survey instruments used in the audit are described in detail in Chapter 4. The instruments used are as follows:

- Light meter
- Data logger
- Infrared thermometer
- Thermo-anemometer
- Digital Stroboscope
- Clamp meter

A calculation of energy use, cost, energy savings, and costs of improvement was performed, and a written analysis of the findings was prepared. Energy conservation options were identified based on the data and calculations from the energy audit. Follow ups with the building managers were made to discuss data obtained from the audit and energy conservation opportunities. The buildings visited on the Chalkville Campus are as follows:

- Iroquois Building
- Gymnasium
- Junaluska Building

- Administration Building
- Chickasaw Building
- Creek Building (dining hall)
- Recreation
- Chapel
- Sequoyah School
- Security Building
- Alabama Building

The buildings visited for the Alabama State Capital Complex site are as follows:

- Gordon Persons Building
- Folsom Building
- Lurleen Wallace Building
- State House Building
- Capitol Building
- Archives Building
- Heating and Refrigeration Building (provides heat for Archives Building)

5.3 Observations and Findings from the Energy Audit

The observations for individual buildings for the Chalkville are listed in Appendix F. The concerns, findings, and recommendations for individual buildings are listed in the next section.

5.3.1 Chalkville Campus (Department of Youth Services)

Prior to the energy audit, a general discussion about the facility was made with the building managers Sandra Douglas and Mike Burr. The following were some of the areas of concerns identified by Mike Burr. The cooling tower on the school was inefficient and had some operational problems. The gymnasium (6830 ft^2) had no air conditioning. The logistics had to be retrofitted. The age of the equipment throughout the facility was a matter of concern. There was problem with the compressor of the walk-in freezer in the Creek building. Wide array of equipment e.g., different types of hot water heaters, heating systems, and air conditioning systems had some problems. Mike Burr and Sandra Douglas identified a need to have additional maintenance staff, trained in HVAC system operations.

General observations about the site are as follows. There were 18 different buildings at the site; floor plans were provided for each building.

There were three shifts of rotating staff. There were approximately 120 employees at the site. There were approximately 85 female students; the capacity of the site is 125.

The site is shut down for two weeks at Christmas time and one week around July 4 (students still reside on campus). Mike Burr identified that a dormitory building (cottage) could be vacated for renovation activities by moving students to another building during the renovation; renovation of the dining facility would require greater coordination and scheduling. All bulbs are fluorescent bulbs unless otherwise specified. The facilities have a mixture of gas and electric heating. The kitchen units are too small given how much they are used. During inclement weather, students are taken by van to the dining hall; in severe weather, the food can be brought to them in their residence halls. Windows are single-paned throughout the facility; the predominant windowing in the student facilities is Lexan (1/4-inch), which is mandatory to prevent potential breakage by residents (students). The Alabama Building uses glass windows. The School also has glass windows and several windows were noted to have severe spider cracks. The Cooling tower (behind the school library) was installed in 2000. It has three blowers. The fan has torn apart and the valve was replaced. The breaker has blown several fuses. The school is used year round.

The general energy recommendations for each building visited on the Alabama Department of Youth Services (Chalkville campus) are as follows. The energy idle down needs to be implemented for 2 weeks at Christmas and one week around July 4. T12 fluorescent bulbs/fixtures should be replaced with T8 electronic fixtures. This will result in approximately 40% energy savings with a payback period of 2 years. Incandescent bulbs should be replaced with CFLs. A CFL lasts 5 to 15 times longer than an incandescent bulb. A 15-watt compact fluorescent bulb yields the same amount of light as a 60-watt incandescent bulb. This will result in an approximately 66% energy savings [8]. Single-paned windows should be upgraded to double-paned throughout the facility. Double-paned windows have a smaller U-factor and lower SHGC, which will reduce the current energy use by approximately 30%. A second pane should be added to Lexan security windows. This will improve the energy efficiency of the windows and result in approximately a 15% savings [21]. The glass windows that have cracks should be replaced. The breaker for the library cooling tower blows fuses and should be replaced or upgraded. A recycling program for plastics, metal, glass and paper should be implemented, reducing energy consumption by approximately 10% [2]. All exit signs should be replaced with LED. Exit signs that have earned the ENERGY STAR operate on five watts or less per sign, compared to standard signs, which use as much as 40 watts per sign. One sign alone can save about $10 annually on electricity costs and can last up to 10 years without a lamp replacement, compared to less than one year for an incandescent lamp [22]. Additional thermostats/air handlers should be installed in large offices to improve temperature. Around 10% of the electricity bills could be saved annually by installing a programmable thermostat [21]. Air conditioning should be added in the gymnasium. Aging equipment throughout the facility should be replaced with Energy Star or ASHRAE 90.1. The walk-in freezer compressor in the Creek building should be repaired. Additional maintenance staff should be trained in HVAC system operations. A fire sprinkler system should be added to nearly all buildings. If all of these recommendations were implemented in the Chalkville campus buildings, energy costs could be reduced by 30 to 50%. The specific recommendations by campus buildings are listed as follows:

Iroquois Building: Air conditioner compressor on roof closest to front should be repaired. The non-working HVAC in the front portion of building should be repaired.

Gymnasium (built in 2000): Air conditioning should be installed. The ceiling should be insulated as needed.

Junaluska Building: The ventilation should be improved. The insulation on Goodman AC Freon lines should be replaced.

Recreation: The air filters in the hallway should be replaced. The holes in the ceiling should be repaired.

Chapel: The water leaks around the rear stained glass window should be repaired.

Sequoyah School: The non-working middle blower on the outside cooling tower should be repaired.

Security Building: The leak in the flat roof should be repaired.

5.3.2 Alabama Department of Finance (Montgomery)

Each building in the Capitol complex has a building manager; Mr. David Connors serves as the Plant Maintenance Supervisor, overseeing five buildings. Mr. Chuck Hicks serves as the space manager. There are rent-paying tenants in the buildings as well as state offices. Fire evacuation diagrams were available from Connors and Hicks. In 2002, Trane completed a complete energy audit of the Capitol complex. There is a preventative maintenance contract with Trane for the chillers. The Governor’s mansion has problems with their HVAC system. The goal was to develop a request for proposal using performance-based contracting.

Preliminary energy audits were conducted at seven state buildings in the Capitol complex. The buildings audited included the Gordon Persons Building, Folsom Building, Lurleen Wallace Building, the Capitol, the Archives Building, the Archives heating and refrigeration building, and the State house. Data were collected during the audits for temperature, relative humidity, lighting, CO_2 content, carbon monoxide (CO) content, and other items (e.g., pressures, air velocities, etc.). The CO_2 content is helpful to determine the adequacy of the ventilation in the facility; concentrations above 1,000 ppm are indicative of poor ventilation [10].

The observations for individual buildings for the Alabama Department of Finance are listed in Appendix E. The general recommendations for each building visited on energy audits with the Alabama Department of Finance are as follows. The Finance Department should bill renters directly for all utilities to encourage savings. Energy Star equipment should be used for state computers left on during the week and off on weekends. All lighting should be placed on computer control to reduce off-hour energy use. Occupancy sensors should be installed in all common areas, including the restroom, cubicles, and office. Replacing T-12 electromechanical ballasts with T-8 electronic ballasts will reduce energy consumption by about 49 watts per fixture. Assuming 60 hours per week and 50 weeks per year (accounting for holidays), this will result in 3,000 operating hours per year. Annual energy savings would therefore be 147 kWh per fixture. With electricity costing $0.06/kWy, annual savings would be $8.82 per fixture [23]. All incandescent bulbs should be replaced with CFLs. Replacing a 100-watt incandescent with a 32-watt CFL will save at least $30 in energy costs over the life of the bulb [24].

Large building HVAC in quadrants should be controlled wherever possible. Special off-hour work areas should be provided to prevent entire floor energy loss. Roof vent systems should be installed to convey moisture away. Small point-of-contact hot water heaters should be used for off-piping installations. A boiler system and chiller economizer should be installed. The freon in chillers should be retrofitted. Emergency power systems off the ground should be raised to avoid flooding problems. Light fixtures should be insulated where ceiling air return is present. A desiccant humidity wheel energy economizer on air intakes should be added. Variable frequency drive (VFD) use should be implemented on air handlers and pumps. The installation of VFDs will ensure that the pumps and air handlers are operating at maximum efficiency at partial load conditions [21]. Operation of all condensate return systems and their repair or replacement should be checked as required. Rain-gauge-driven outdoor sprinkling systems should be added to avoid over watering. Recycling of paper, glass, metal, and plastic should be made mandatory. This will result in approximately 10% energy savings [2]. Only approved personal electric space heaters should be used in problem temperature zones. A general usage and demand charge study should be conducted to minimize energy costs. A energy savings of 20-40% in total energy bills could be achieved, if all of these recommendations are implemented. The specific building recommendations by each building are as follows:

Gordon Persons Building: The positives include computer controlled HVAC controls air conditioning and heat by High/Low Trip Set. The recommendations for the building are as follows. Newer solid-state elevator controllers should be evaluated to reduce heat. Magnetic ballest/T12 should be replaced with electronic T8 throughout the building. This will result in approximately a 40% savings [8]. Computer controls should be added to existing off-hour lighting and the controls must be turned on every four hours (call-in). Economizers should be added where missing on HVAC. Under the right conditions, free cooling or a water-side economizer system can generate significant energy savings. In cooler, drier climates, water-side economizers can provide over 75% of the cooling requirements; in warmer climates they may provide only 20% [21]. Hot water off of chiller condenser should be made. Adsorption dehumidifier should be added where possible. A recycling program should be supported and made mandatory.

Folsom Building: The positives include sophisticated computer room power generator and uninterruptible power supply for transients which ensures fail safe power delivery and operation. System can feed electricity back into grid which results in energy savings depending on the load and supply. The recommendations for the building are as follows. The Evaporative cooling tower should be replaced with Energy Star one. This will result in approximately a 15% energy savings [21]. Heat/cooling energy should be captured from building exhaust (presently lost through leakage). Replacement of obsolete Robert Shaw controllers should be evaluated. Noise protection should be added to chiller areas. The energy generator should be elevated above flood level. An economizer should be added, particularly on data-center condensers, which could easily adapt for hot water production as the unit is outside at ground level. Old incandescent exit signs should be replaced with LED’s. One sign can save about $10 annually on electricity costs and can last up to 10 years without a lamp replacement, compared to less than one year for an incandescent lamp [22]. Many areas of the building are lit too brightly in excess of 100 fc. Such areas should be de lamped wherever possible. Operating a combined heat and power cycle should be considered, i.e., make steam/hot water with the emergency generator one or two days a week. The duty cycle should be checked with the manufacturer.

Lurleen Wallace Building: The positives are that some rooms have occupancy sensors. These controls can save energy in a room when it is unoccupied. There is aluminum can recycling. The recommendations for the building are as follows. The leaking air compressor in the basement should be repaired or replaced. The hot water heater insulation should be repaired. Economizers should be added.

Capitol Building: The positives include a computer control system so that data can be monitored easily. Air handler pre-filters lengthen life of the air handlers. There is a novel lawn-watering system based on actual rainfall that prevents the use of excess watering. Point-of-use hot water heaters were used where boiler water was unavailable, which reduced heating of water in bulk quantities. Auto-flush toilets used in the facility saved water. The recommendations for the building are as follows. Outdoor lighting of the dome should be reduced, and ground fixtures damaged by water should be replaced. Reducing indoor lighting during off-hours should be considered. Outside lighting tie should be added to computer for additional savings. Standard personal area heaters should be developed to enhance safety and reduce fires. 60 interior dome flood lights should be replaced with CFLs. An architect can be consulted for lighting values. This will save approximately 65% of the energy consumed [21].

Archives Building: The positives include an adsorption dehumidifier wheel on incoming air that uses waste heat for regeneration, computer controls, and CO_2 sensors used to adjust outside air intake which exact amount of air to be used. The public area already uses CFLs which save approximately 50 to 60% of the energy normally used in lighting. The recommendations for the building are as follows. 15 September, 2004 recommendation should be reviewed to replace windows and insulation and a boiler economizer should be added.

Mechanical Heating and Refrigeration Building for Archives: The positives include new separate HVAC building that uses newer high-efficiency Trane Chillers, which are 50 to 60% more efficient than the older ones. There is a heat recovery system in new building. The recommendation for the building include addition of a cooling tower.

State House Building: No indication of trouble with energy conservation techniques was found in this building.

5.4 Recommendations for All State Facilities in Alabama

The following is a list of recommendations that can be applied to all Alabama state buildings [2, 3, 25].

5.4.1 Replacement of old heat pumps with Energy Star pumps

Energy Star rated heat pumps should be used throughout the facility. Assume that the facility is using heat pumps of 100,000 BTU/hr, an EER of 11.5 BTU/Whr, and a coefficient of performance of 11.5. If one of these units is replaced with Energy Star rated units of the same capacity,14.1 BTU/hr EER and 3.3 COP, an energy savings of approximately $3,200 can be obtained with a payback period of less than one year.

5.4.2 Use of programmable Energy Star thermostats

Assume that the cost to install a single unit is $70 and energy consumption is approximately 6000 kWh. With an energy savings of 10% for replacing the thermostats with energy efficient ones, the payback period is approximately 14 months.

5.4.3 Replacement of incandescent lamps by compact fluorescent lamps

Assuming wattage used per lamp for compact fluorescent lamps = 15 watts, and assuming wattage used per lamp for incandescent lamps = 60 watts. Average cost of electricity = $ 0.06 / kWh. Assuming initial cost is $85 for incandescent lamp and $150 for compact fluorescent, the simple payback period to retrofit a single incandescent lamp with compact fluorescent lamp is approximately 18 months.

5.4.4 Replacement of old boilers with Energy Star rated boilers

Boilers older than 15 to 20 years should be replaced with Energy Star rated new boilers. Replacing an old boiler with 100,000 BTU/hr existing capacity operating at 75% annual fuel utilization efficiency (AFUE) with Energy Star rated boiler of 85% AFUE will result in approximately $900 of annual energy savings with a payback period of approximately 18 months.

5.4.5 Replacement of incandescent lamps by LED's in exit signs

Assuming wattage used for a LED unit = 5 watts, assuming wattage used for an incandescent lamp = 40 watts, and assuming initial cost for incandescent lamp is $75 and $165 for compact fluorescent, the simple payback period to retrofit a single incandescent lamp with LED is approximately 21 months.

5.4.6 Replacement of single-paned windows with Energy Star double paned windows

The double-paned Energy Star windows have a U-factor of less than 0.65 and SHGC factor of 0.3 which, makes them more energy efficient. The payback period for this type of replacement can be up to 5 years.

Table 2: Energy Savings and Payback Period

Device	**Section**	**Payback (months)**	**Approximate Savings (%)**
Heat pumps	5.4.1	12	40
Thermostats	5.4.2	14	10
CFLs	5.4.3	18	65
Boilers	5.4.4	18	10
LED's	5.4.5	21	80
Double paned windows	5.4.6	60	40

CHAPTER 6

SUMMARY AND CONCLUSIONS

This project involved performing preliminary energy audits at various state buildings in the State of Alabama. The research team assisted the Alabama Department of Economic and Community Affairs (ADECA) in developing a 1-page survey to assess building utility costs. Appendix B provides a copy of the survey form sent to the various state agencies. Over 700 responses have been received in response to the survey. UAB and ADECA reviewed and analyzed the data from the survey responses in order to identify specific facilities for conducting the preliminary energy audits. Four different state agencies were identified where preliminary energy audits were conducted: Bryce Mental Health Hospital (14 buildings), Department of Youth Services/Chalkville campus (11 buildings), Fort Taylor Hardin (2 buildings), and the Alabama Department of Finance/Capitol complex (7 buildings). A total of 34 buildings were audited. Facility executive summaries and building reports were prepared, identifying areas where low-cost/no-cost energy conservation measures could be employed. The primary objectives of the thesis, to conduct energy audits and recommend ECMs were met. The biggest potential for energy savings was found on the Chalkville Campus. Due to the age of the equipments at the Chalkville site, there is plenty of room to replace the existing equipment at the facility with Energy Star equipment, and hence maximum energy savings can be obtained at this site. This facility is the oldest of all the facilities where energy audits were performed. The facility also had lot of leakages and hence had the maximum potential for energy savings. Examples of some measures are as follows:

- Old heat pumps should be replaced with Energy Star pumps (payback period 12 months)
- Programmable Energy Star thermostats should be used (payback period 14 months)
- Incandescent lamps should be replaced by compact fluorescent lamps (payback period 18 months)
- Old boilers should be replaced with Energy Star rated boilers (payback period 18 months)
- In exit signs, incandescent lamps should be replaced by LEDs (payback period 18 months)
- Single-paned windows should be replaced with Energy Star double-paned windows (payback period 5 years)

These recommendations should be implemented throughout state buildings in Alabama. The payback period of replacements is also less. The research team with the help of ADECA, carried out energy audits in several state buildings in Alabama. The primary concern carrying out detailed audits is the revenue. The state does not have enough capital to carry out energy audits in all of its state buildings. Also due to the primary use of the Chalkville facility, it does not get the same attention as the Alabama State Capitol Complex. The facility also lacks the funding to support the energy audits. ESCOs should be contracted to save further energy in the state buildings such as

Chalkville site. The ESCOs invest money for the energy audits and recover it from the reduction in electricity bills. The energy savings resulting from this project were based on performing energy audits in various state buildings. The energy savings and economic savings were estimated based upon the guidelines presented in the STE Guide for Calculating Program Annual Energy Savings, published in 2003. The energy savings were calculated using the formula E = A*B*C, where E = Energy savings in BTU or dollars, A = BTU saved or dollars saved for a commercial building in state of Alabama, B = Number of buildings, C = rating factor varies from 1 to 7 (1 = New building, 7 = Shack). The estimated energy savings for a commercial building in the state of Alabama is approximately 240 million BTUs or $1500 [26]. The estimated energy savings for the Chalkville site (11 buildings) is 8000 million BTUs (240*11*3 and assuming a factor of 3) and an associated economic savings of approximately $50,000. Similarly the estimated energy savings for the Alabama State Capitol complex buildings is approximately 3,400 million BTUs (assuming a factor of 2) and an associated economic savings of $22,000.

6.1 Difference in the two facilities

The Chalkville campus is a much smaller and older facility than the Alabama State Capitol Complex. The average size of a conditioned or heated space for a building at Chalkville site is approximately 7,000 sq ft, compared to 500,000 sq ft for the Alabama State Capitol Complex. Also most of the buildings at Chalkville site are 50 to 60 years old, compared to 20 to 30 years for Alabama State Capitol Complex. As a result, even though the size of the facility is small, the Chalkville facility has a greater potential for energy conservation. There are lot of leakages through pipes and ducts and the mechanical equipment throughout the facility is very old. The Alabama State Capitol Complex is comparatively newer. Some of the buildings even have latest technologies for energy conservation. Some of these technologies from the Alabama State Capitol Complex can be implemented in the Chalkville Campus to save more energy. For example, point-of-use hot water heaters can be used to reduce boiler loads and also where boilers are unavailable, and flush toilets can be used to save water.

6.2 Recommendations for future work

Energy consultants or ESCOs should be contracted to perform a detailed energy audit on the Chalkville campus and Alabama State Capitol Complex buildings. All new equipment to be installed in the near future should be Energy Star rated. A similar energy audit should be carried out in all of the state buildings in Alabama.

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APPENDIX A

CASE STUDY

Audit Report for San Diego Office State Building (case study): The Department of General Services state office building is located in San Diego. It has approximately 350 employees and an area of 174,100 square feet.

Summary: In June 2000, the San Diego State Office Building peak kilowatt (KW) load was 1,106 KW (1048.26 Btu/s). Between June 2000 and 2001, the facility implemented a slew of conservation improvements, which resulted in a 21% reduction in peak KW demand and a 33.9% reduction in energy used. The building's peak KW load dropped to 873.6 KW (828.01 Btu/s).

Plan: The building manager collected all directives from the director of the Department of General Services (DGS) regarding energy usage, temperatures for offices and domestic hot water and lighting levels for office workers. The manager then reviewed the building's compliance with those directives, and found that the building was providing more than what was required. Building staff proceeded immediately with project implementation, targeting an overall reduction of 25% or more depending upon the good will and tolerance of the clients. Areas identified for operational changes were: heating, ventilating and air conditioning (HVAC), lighting and plug-in loads.

The second task was to educate staff about how to meet the energy savings goal. The building manager involved the entire staff in project implementation and held them accountable for achieving the 25% savings. Key members of the staff were the chief engineer, janitorial supervisors, the maintenance mechanics, building maintenance workers and stationary engineers.

Programs: The following conservation measures were implemented to achieve the energy goals:

- Lighting: Lights were turned off when rooms were not in use. All lighting was on a lighting control system. Lighting was reduced in rooms with more than one light switch. Overhead lighting was turned off and task lighting was used. Custodial personnel turned on lighting only while cleaning and then lights were turned off; they worked in teams to reduce lighting. Safety and security lighting were kept at lowest acceptable level; decorative lamps were removed. Outside the building, only parking lot security and entrance/exit lighting were turned on. The lamps and ballasts were removed and stored for reuse. In the corridors, ballasts from fixtures not located near suite doors, restrooms, stairwell entrance, fire alarm pull boxes and fire hose cabinets were removed. All lighting at elevator lobbies, except for what was necessary to read the directory and elevator call buttons clearly were turned off. Signs were made for all light switches and power-using equipment that reminded tenants to switch off or unplug lights/equipment. Stickers on light controls were installed to identify which controls were to be turned off during each stage.

- HVAC: Start and stop times of the HVAC system were curtailed to what was needed for official building operating hours. The DGS director provided these times in writing. Room temperature was maintained at 68 degrees F in the winter and 78 degrees F in the summer. Actions were taken through 455 programmable thermostats. HVAC systems were set to allow building air temperatures to fluctuate ±4 degrees. HVAC economizers were used to effect optimum duty cycle and to optimize compressor startups**.** Domestic hot water temperature was set at 120^{o}F at the hot water heater and at 105^{o}F when water gets to the sink. Boiler temperature was set for minimum operation and timer controls to limit run times. New controls on chillers were installed.
- Weatherization: Solar coverings were installed in the west and south side of the building
- Computer/office equipment: At least one essential computer and email server for communications was identified. Except that PC and monitor all other PC's were shut down. All video monitors and computers were set to power down after five minutes of non-operation. All but one of the nonessential duplicating systems and equipment, copiers, printers, scanners and fax machines were shut down. Power save mode on printers and copiers were enabled. All but one printer were turned off.
- Building plug-in loads: Space heaters and nonessential devices were unplugged. Two to three drinking fountains per floor were disconnected. Number of coffee

pots and cooking devices used in kitchens were reduced. The use of nonessential appliances, coffee machines, microwaves and coolers were limited for bottled water. Some equipment in the kitchen, such as electrical range and portable refrigerators were removed. Also refrigerators were consolidated.

- Employees: The building manager taught, coached, counseled and trained building occupants on steps to take at work and at home to reduce energy use. The director of DGS and acting chief of Building Property Management (BPM) helped solicit tenant involvement. The building manager presented energy reports, including savings comparison charts and WebGen profiles, at all tenant and staff meetings.
- Budget and Finance: There was no budget. Building managers had to implement no-cost conservation actions only.

Results: In June 2000, the San Diego State Office Building at 1350 Front St. had a total peak KW load of 1,106 (1048.29 Btu/s). In June 2001, total PKW load dropped to 873.6 (828.01 Btu/s). In June 2001, compared with June 2000, the San Diego State Office Building realized a 21% reduction in peak KW demand, a 33.9% reduction in overall energy use for the month, and Cost savings of approximately $6,800 for the month.

Lessons learned: San Diego State Office Building learned that building staff needed to continue to closely monitor energy plans and operations, even after the “crisis,” to ensure that energy conservation continued.

APPENDIX B

ALABAMA STATE BUILDINGS ENERGY USAGE SURVEY FORM

SECTION I: FACILITY DATA

1. State Agency ____

2. Name of Building ____

3. Street Address of Building ____

4. City ______________________________ Zip Code ____________________________________

5. Primary Use ____

6. Building Owner ____

7. Building Manager ____

   Phone: ___________________________

8. Person completing survey____

   Phone: ____________________________

9. Year constructed ____

10. Year of last major remodeling that would significantly effect building energy

    use: _________________________

11. Any major change planned to occur during the next two years that could significantly affect

    energy use?____

12. Please describe the typical hours of operation for your faciltiy ______________________

13. Give the total square footage of conditioned space ________________________________

14. If the total areas, which are heated and cooled, differ in size, please describe their respective sizes____

SECTION II: ENERGY CONSUMPTION DATA

Please summarize utility consumption and costs for a recent 12 month period. The cost data is most important. If only the utility cost data is available, please submit the cost data without the usage data.

Total electricity cost for a year ($): _______________________,

Ending in the month of _______, year____

1. Total electricity usage for a year (kilowatt hours): ___________,

   Ending in the month of _______, year____

2. Natural gas cost for a year ($): ___________________________,

   Ending in the month of _______, year____

3. Natural gas usage for a year (therms or ccf): ________________,

   Ending in the month of _______, year____

4. Propane cost for a year ($): _____________________________,

   Ending in the month of _______, year____

5. Propane usage for a year (gallons) _______________________,

   Ending in the month of _______, year____

6. Water cost for a year ($): ______________________________ ,

   Ending in the month of _______, year____

7. Water usage for a year (gallons) ________________________ ,

Ending in the month of _______, year____

Comments:

APPENDIX C

SURVEY FOR ENERGY AUDITS

Building	Total Sq ft	Electricity ($)/yr	Electricity (kw)/yr	Natural Gas ($)/yr	Natural Gas	Water ($)/yr	Water (gallons)/yr
Alabama Public TV	20700	30000	458618			1098	169000
The Plaza Building	16700	20451	295758				
Main Office	65620	63192	756000			1367	288000
Central Office	250000	301625	6327590	40475	52558804	34049	7351000
Building L	60000						
Bridge Warehouse	0	22682	475891	1446	1880298		
Communications Building	2400	3780	79315	690	905		
Divers warehouse	624						
DOT Annex	70000	3996	50686	1432	1006		
Traffic Signal Shop	9400	3780	79315	26201	3402	1677	419250
Sign Shop	22800	63008	1322	5309	6486	1677	419250
Archives and History Museum		126456	17320264	104318.34	797016	8903	1680
State Records Center	273620	12000		8000		1000	
Staton	109708	110128	2208690	1			
Kilby CF	176662	224077	3476861	320539	31424300	214133	
Tag Plant	0			368	55		
Metal Fab Plant	0	13038	126120	42001	652		
Fountain Fleet Services	0	3056	32303	1500	1126		
Bibb County Correctional Facility	176293	210748	3178864	463041	52033	3021179	97654299
Tag Plant	0			368	55		
Metal Fab Plant	0	13038.2	126120	4200.6	652		
Fountain Fleet Ser	0	3055.94	32303	1499.74	1126		
Kilby Print Plant	14000	28000	24771	5800	7044		
Alabama Correctional Industries	63359	41839.87	481520	16583.92	1525400	7104.59	1068000
Horse Bann	568	1051.72	16315				
Saddle House	552	2467.45	34433				
Barn	260	4789.88	77745				
Ventress Box	6000		26910				

Building	Total Sq ft	Electricity ($)/yr	Electricity (kw)/yr	Natural Gas ($)/yr	Natural Gas	Water ($)/yr	Water (gallons)/yr
Draper Furniture Plant	13048			6050.32	5518		
Bibb Furniture Plant	0			6050.32	5518		
Alabama Correctional Ind.	15617	12592.4	136800			120	
Data Entry	1200	1783	17044				
Walter J. Hanna	20232	22577	313110	8353	7417	964	273
Henry B. Graham	24195	20465	241067	9071	8006		
Julius W. Hicks	30498	12098	138497	3074	2640	112	42
George C. Wallace	63267	55221	667337	5576	4876	2133	464
Taylor Hardin	37185	44930	490962	12559	11136	1306	277
Opelika National Guard	27029	12084	158363	4055	3371	963	172
Ralph W. Adams	25972	15097	184630	4415	3897	135	126
Union Springs National Guard Armory	20099	7128	72604	6515	4381	228	812
Pete Phillips	17534			2417	2233		
Charles P. Bailey	23533	12425	157235	8795	7678	595	125
Eugene Nall	18815	6313	52447	1638	1321	154	71
Charles A. Rollo	30344	28889	11244	3952	3943	523	91
Ft. Beveridge	11725	4193	28116	191	71	634	245
Berry National Guard Armory	11725	2961	4763	1427	934	228	
arm Forces Reserve Center	31540	141032	1949160	9361	8110	357	56
S. Ralph Terhune	19158						
Dow Sport	12070	3508	31924	1790	1491	104	26
Don Bryant							
95 Airport Rd	25430	5387	47840				
Bridgeport National Guard Armory	12070	1931	15313	78	1	429	52
Wendell K Taylor	18198	4314	41360	295	187	207	79
Bob Locke	11725	3318	20760	4876	213	94	154
Calera National Guard Armory	11725	2701	19157	3634	3554	184	2
Camden National Guard Armory	11725	1829	13706	1268	1268	207	55
Carbon Hill National Guard Armory	11725	1478	7748				
Centre National Guard Armory	11725	2801	29849	2648	3238	211	33
I Judson Sneed Ctr	14499	9169	96306	2369	2140	300	64
Ft Chatom	11725						
Ervin A. Byrd	19071						

Building	Total Sq ft	Electricity ($)/yr	Electricity (kw)/yr	Natural Gas ($)/yr	Natrual Gas	Water ($)/yr	Water (gallons)/yr
Cullman National Guard Armory	23749	6080	77276	3556	3056	399	98
Andrew Jackson	11725	4371	32428	4637	3937	281	50
William A. Hornsby	22016			3124	2697	159	75
Quarles/ Flowers							
Flowers	28405						
Demopolis National Guard Armory	23165	12358	121708	9946	8854	4220	2413
Buntin Parsons	23772	8482	126157	3092	2662	324	104
Double Springs National Guard	18333	3981	23637	1783	1334	1136	516
Charles L. Rowe	16170	2163	23213	1942	1611	184	59
Raymond Blackmon	20878	8335	62080	2239	1939	707	149
Nathanael Greene	11725	8461	52806	5827	5028		
Ft. Riel	11725	1365	16053	444	299	104	4
Tom Bevill	30845	7677	44827	752	675	505	10
Florala National Guard Armory	15068	3137	19669	409	322	116	4
Cromwell / Pickens	25399	14248	193920	5232	3942	355	120
William L Smith	15382	5168	60715	1979	1480	874	220
Thomas H Moorer	11725	3948	35616	705	1977	924	278
Ft. Sequoyah	26195	7868	106187	2992	3977	974	272
Clarence F. Rhea	21775	9452	92876	1307	940		
Fred M. Fleming	11725	7089	67119	3336	2281	457	157
Georgiana National Guard	12070	3450	18638			128	4
William N. Griffin	18248	3543	28519	777	693	370	63
Tomas E. Seay	12070	2988	24540	1238	1027	84	56
Robert E. Steiner	11725	3620	22720	1342	1089	155	21
Luke E. Reed	24734	9263	81469				
Guin National Guard Armory	11725	1572	16678				
R M Kelley Jr.	16089	3637	40328				
Billy F Roberts	18616	3594	23963				
Hamilton National Guard Armory	22906	14445	99739	6116	99739		
Doil b. Sawyer	11725	2596	39734	2073	1488	68	5
Ferrell Vest							
640 Vaughn Bridge Rd	11725						
Ft. Henry	11725	2888	28586	1344	1093	720	
Heflin National Guard Armory	11725	2463	17218	3379	319	124	9
W C Mulkey	15795	12840	122598	2431	2016		
Ft. R W Shepherd	56532	26996	316555	6264	5564	2183	298

Building	Total Sq ft	Electricity ($)/yr	Electricity (kw)/yr	Natural Gas ($)/yr	Natrual Gas	Water ($)/yr	Water (gallons)/yr
Raymond W Jones	11725	7645	111729	3400	3702	281	90
Jackson M. Balch	40350	15959	243946	8829	9703	496	289
Isaac Push	16634	6206	70637	2585	2240	402	143
John H Forney	34963	10739	113055	5763	5289	1807	723
Neil L Boteler	18100	7673	79207	2081	1613	841	49
Linden National Guard Armory	19893	11218	102809	3506	2914	269	60
J C Reeves	11725	1506	11697	1307	1236		
James D. Finlay	14108	4431	48539	2428	2065	155	100
Marion National Guard Armory	16652	7592	57186	4433	4478	322	32
Millport National Guard Armory	19848	5547	6793	2392	2183		
Ft. Whiting	55193	26518	267592			3260	112
F A McCorkle 1620 S Broad St	31500	21546	281273	2552	1969	2853	918
Ft. Short Millsap	11725	3809	28205	1213	911		
SMD & Annex (TAG)	47114						
Old CSMS	63267						
Herman L Brewington	11725	1880	14905				
Paul L Sawyer, Jr.	11725	5070	46484	1835	1537	211	82
Powell Shamblin	11725	4331	41629	2714	2184	150	29
Northport National Guard Armory	25172	17736	191645	3720	3088	844	243
Oneonta National Guard Armory	28910	10859	109241	4326	3425	520	66
Opp National Guard Armory	11725			645	470		
Aubrey G. Hicks	11725	4803	26881	2927	2358	281	40
Henry B Steagall	12565	7089	669346	34	470	907	408
Henry H. Cobb Jr	22576	7692	65201	2413	1940	215	79
Jabe Brassell	11725	7699	55862	1911	1495	289	105
Prattville National Guard Armory	19495	12267	107907	2281	1942	320	90
Roanoke National Guard Armory	11725						
Conder P. Ray	18616						
Samson National Guard Armory	18209	4768	55749				
W W Quarles	11725			2836	2911	270	23
Selma National Guard Armory	42125	27252	311368	7174	6232	825	244
Joseph H Nathan	11725	5247	64549			640	35
Neil Metcalf	11725			2655	1838	546	52
Springville National Guard Armory	11725	3355	35760	3211	2873		

APPENDIX D

PHOTOGRAPHS FROM ENERGY AUDIT

Photographs from Energy Audit at Chalkville Campus

Typical Lighting (Compact Fluorescent Tubes)

Typical Chiller System (HVAC)

Typical Boiler System

Typical Basement (Boilers and pumps)

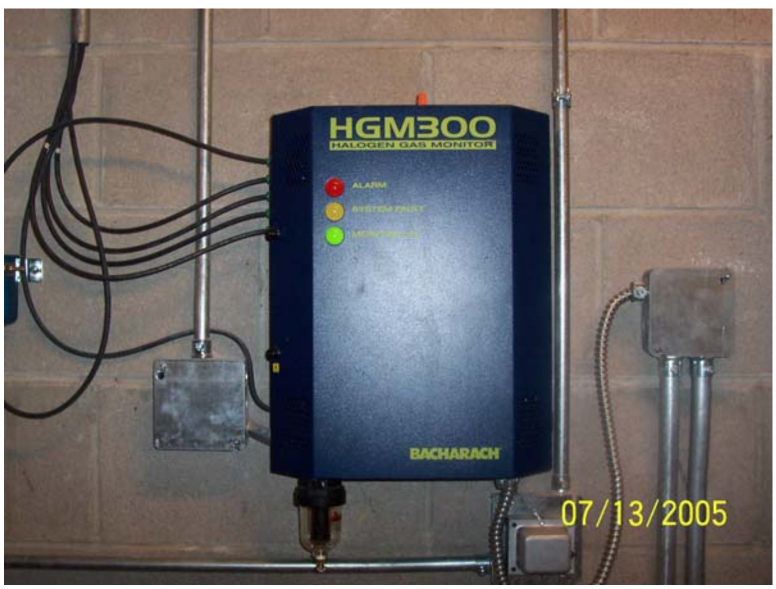
Water Pumps

Photos from Energy Audit at Alabama State Capitol Complex

Folsom Building Recirculating Pumps

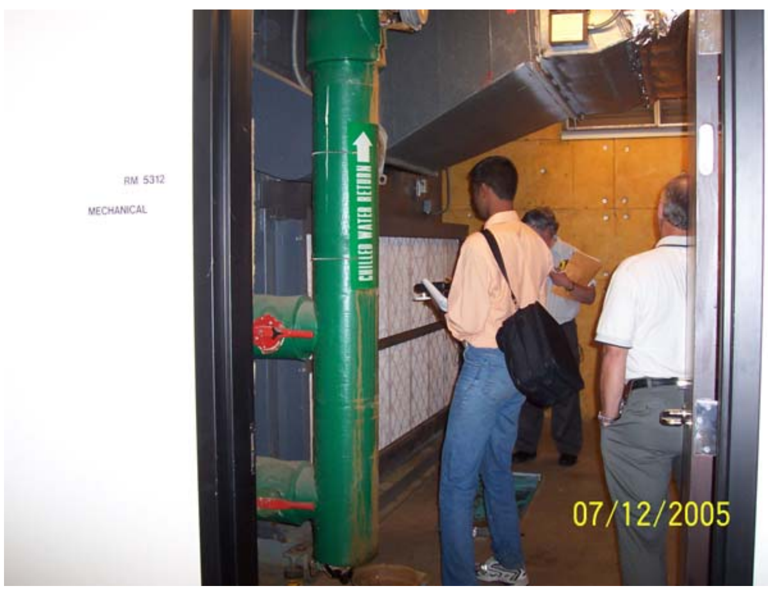
Lurleen Wallace Building Recirculating Pumps

State House Building Boilers



Archives Building Halogen Monitor

Folsom Building Air Handlers



Person’s Building Air handlers

Person’s Building Roof

Folsom Building Cooling Tower

Folsom Building Condensers

Folsom Building Measurements

Capital Building External Lighting

Capitol Building Rain Gauge

Capitol Building Under Sink Hot Water on Demand

APPENDIX E

OBSERVATIONS FROM PRELIMINARY ENERGY AUDITS AT CHALKVILLE CAMPUS

Room	**Description**	**Temperature**	**Relative Humidity (%)**	**Lighting (foot candles)**	**CO_2 (ppm)**	**CO (ppm)**	**Other**
				Iroquois Building			
Outside of building		91.7°F (33.2°C)			303		Three 3.5 ton Carrier air conditioning units on roof
Hair Styling Room		92.2°F (33.4°C)		1840 lumens (under 4 bulbs) 380 lumens in non-lit area 233 lumens in other non-lit area	226		Use T12 fluorescent bulbs; use hot water heater in room
Laundry Room		92.0°F (33.3°C)					1 light fixture with 2 fluorescent bulbs
Main Part of Building							Building uses old exit signs with fluorescent bulbs

Room	Description	Temperature	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	CO (ppm)	Other
Classroom No.1		91.6°F (33.1°C) 32.0°C in air vent 33.4°C in other air vent 29.6°C on wall			400		Each light fixture is separately controlled
Dining Area		25.7°C (return air) 20.8°C (in air vent)					Has 15 wall fluorescent bulbs; has 16 100-watt bulbs in fire place area; Air Velocity: 250 ft/min in vent; Most air vents did not appear to work.
Bedrooms		18.7°C in air vent					Use 2 double light fixtures; Use 4 bulbs total of 100-watts each; Air velocity in vent: 250 ft/min
Bathroom		84.9°F (29.4°C)		71 – 86	370		Renovated in 2004, has 6 double fluorescent light fixtures; other bath-room had 4 fixtures
Main Hallway							8 fixture with 4 bulbs/fixture; had 9 incandescent 100-watt bulbs (2 were burned out) – have mirrors to focus light; have old boiler in basement (not used since at least 1991).

Room	Description	Temperature	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	CO (ppm)	Other
				Gymnasium			
	Inside gymnasium	28.3°C (on wall) 30.1°C (on louvers) 89.2°F on other wall (31.8°C)			208-230		16 light fixtures; 5 heaters; 2 large fans; 2 louvers on opposite wall; R19 insulation on roof
				Junaluska Building			
Main building							Uses mechanical ballasts and old fluorescent exit signs
Hallway		89.2°F (31.8°C)			680		Uses 4 short fluorescent bulbs in hall-way fixtures; also three double U-tube fluorescent bulbs
Dining Room							Has 6 light fixtures with 2 U-tube bulbs/ fixture; have steam table when need to have food from dining hall brought in (due to bad weather)

Room	Description	Temperature	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	CO (ppm)	Other
			Administration Building				
Mechanical Room	Room	88.4°F (31.3°C)			418		Hot water heater has 91-gallon capacity (1150 BTU/hr); five air conditioning units were installed between 1983 and 1990; Has two 2-bulb fluorescent fixtures (42-inch length)
	Hot water heater	46.1°C					
	Cooler water	35.4°C 37.4°C					
	Blended water (sent to building)	29 – 32°C					
	Exhaust lines sent to building						
Orientation Room		88.8°F (31.6°C)		45	545		Uses mechanical ballasts
Hallway		88.3°F (31.3°C)		21.7 40.1 (directly under lights)	575		
Bathroom		19.8°C on wall 16.3°C in air vent		18.5			

Room	Description	Temperature	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	CO (ppm)	Other
Office	Office equipment included Xerox machine, Dell computer, fax machine – all were Energy Star	26.1°C (wall) 14.1°C (vent) 83.6°F (room) (28.7°C)	54		449		Uses 4 fluorescent bulbs/fixture (~4-ft long); overhead air vents need cleaning (lots of dust)
Stairwells		83.3°F (28.5°C)		21.2 31.9 (on up-stairs landing)	970		Uses 4 double bulb fluorescent light fixtures; Very stuffy in stairwells
Upstairs Hallway		19.4°C in room; 24.9°C on wall					
Upstairs Office		83.3°F (28.5°C)			368		Uses four 96-inch fluorescent bulbs (60-watts); two 15-watt incandescent bulbs above fireplace
Clothes Stockroom		84.0°F (28.9°C)		95; 88.4 directly under lights 10.3 under incandescent bulbs	373		Has 4-6 inches of blown fiberglass insulation in attic area; Very stuffy in attic area

Room	Description	Temperature	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	CO (ppm)	Other
			Chickasaw Building				
14 rooms for students	This building is equipped with a sprinkler system (the only building on campus)						Has 3 furnace units (2- 140,000 btu and 1- 90,000 btu unit) purchased in 2003; reception area has 2 ceiling fans
Hallway							Has 12 double U-tube fluorescent bulbs and 10 double incandescent bulb fixtures
Lounge /foyer				73.6 (with lights on)			Exit signs use two 15-watt incandescent bulbs
Bedroom				4.8			Has one incandescent light/room
Dining Room		84.5°F (29.2°C)			267		8 light fixtures with 2 U-tube fluorescent lights/fixture; 4 light fixtures in pit area
Service Kitchen		84.2°F (29.0°C)			265		Four light fixtures with two 4-ft tubes/ fixture

Room	Description	Temperature	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	CO (ppm)	Other
Linen Cabinet		81.8°F (27.7°C)		28.1	450		
			Creek Building				
Dining Room		86.7°F (30.4°C)			338		
Chiller Room		8.8°C (wall) 6.3°C (fans) 42°F (gauge) = 5.6°C					
Freezer		-6.6°C (fan) 1.1°C (wall)					
Kitchen	Kitchen has Garland oven/ burners, Fry master, Hobart ovens	80.1°F (26.7°C)			292		Exhaust vents are very dusty and need to be cleaned
Storage area for canned goods		80.3°F (26.8°C) 24.3°C (wall)			448		
Dish Washing area		152°F (wash) (66.7°C)					Wash cycle operates in 150-160°F range; rinse cycle operates in 140-150°F range

Room	Description	Temperature	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	CO (ppm)	Other
Recreation Building							
Group room		15.1°C (vent) 23.7°C (wall) 84.4°F (room) (29.1°C)		17.5	505		Two light fixtures, one with two 4-ft fluorescent bulbs, and one with four 4-ft fluorescent bulbs (only 2 bulbs in fixture)
Hallway							Filters in return air vent need replacement; very dirty. There are holes in the ceiling tiles.
Recreational area		11.8°C (vent) 20.8°C (wall) 80.7°F (room) (27.1°C)			420		Eight light fixtures with two 4-foot fluorescent bulbs
Chapel Building							
Chapel (built in 1967)	Main room Return air Wall Air vent	82.8°F (28.2°C) 25.6°C 25.2°C 19.2°C		1.9 (with overhead lights on)	354		20 light fixtures over chancel area; 10 overhead light fixture in chapel with 4 light bulbs each; Leaks around rear stained glass windows

Room	Description	Temperature	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	CO (ppm)	Other
				Sequoyah School			
Classrooms	Chiller handles whole building with air handling boxes						Nine light fixtures with 4 x 4 arrays
Restroom							Four fluorescent tubes/fixture; one with 4 tubes, and 1 with 2 working tubes.
Library				120			Uses new electronic ballasts; 18 light fixtures with 4 fluorescent bulbs
				Alabama Building			
Used for orientation; not used as regular dormitory	Vent Wall	15.2 – 22.7°C 22.5°C		38.9; 67.1 under lights			Uses two 4-tube light fixtures
Restroom		84.1°F (28.9°C)		50.9 under lights	410		Has one light fixture with 4 fluorescent lamps

Room	Description	Temperature	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	CO (ppm)	Other
Bedrooms							Has one 100-watt incandescent bulb
			Security Building				
Main office area		26.8^{o}C (wall) 10.8^{o}C (air conditioner) 86.1^{o}F (room) (30.1^{o}C)		49.2 (under lights)	642		Has a flat roof that leaks; large hole in ceiling. Four light fixtures with 2 fluorescent bulbs/fixture; Mechanical ballasts

APPENDIX F

OBSERVATIONS FROM PRELIMINARY ENERGY AUDITS AT ALABAMA STATE CAPITOL COMPLEX

Room	**Description**	**Temperature**[a]	**Relative Humidity (%)**	**Lighting (foot candles)**	**CO_2 (ppm)**	**Other**
		Gordon Person Building				
Office Room			23	58.5		
Boiler Room		28^{o}C (82.4^{o}F)		20		
Cooling towers	Air Water inside cooling tower	26.2^{o}C (79.2^{o}F) 27.0^{o}C (81.7^{o}F)				
Engine Room (Room 1120)	Chilled water return	50^{o}F (10^{o}C) (both right and left units)				
	Pump	86^{o}F (30^{o}C) – (right) 83^{o}F (28.3^{o}C) – (left)				51 psig (right) 22 psig (left)
	Chilled water supply	42^{o}F (5.6^{o}C) –(right)				41 psig (right)
	Pump	46^{o}F (7.8^{o}C) – (left) 92^{o}F (33.3^{o}C) – (right) 82^{o}F (27.8^{o}C) – (left)				41 psig (left)

Room	Description	Temperature[a]	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	Other
Generator Room	Room	29.1°C (84.4°F)	55	11		
	Wall	29.4°C (84.9°F)				
	Control panel	31.1°C (88.0°F)				
		19.8°C (67.6°F)				
Exit by Elevator	Mechanical ballast		39	28.6		
5th Floor Hallway		23.7°C (74.7°F); 80.5°F (26.9°C)	54	54 (under light); 28 (at desk)	415	
5th Floor Office		79.7°F (26.5°C)		70	440	
Air Handling Room	Room	26.0°C (78.8°F)			344	
	Chilled water supply	15.9°C (60.6°F)				
	Chilled water return					
	Pump	13.9°C (57.0°F)				
	Outside air					
	Automatic sprinkler system	36.2°C (97.2°F)				
		26.1°C (79.0°F)				
		24.6°C (76.3°F)				
Stairwell	Stairwell	30.8°C (87.4°F); 79.3°F (26.3°C)	36	42; 36	780	

Room	Description	Temperature[a]	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	Other
Enclosed Courtyard Area	Enclosed courtyard area	21.2°C (70.2°F)	42	50		
Print Shop Area	Print shop area	21.9°C (71.4°F)	42	62	580 (general room); 1167 (with people around it)	
Room 1345 (Revenue)	General room	27.4°C (81.3°F); 75°F (23.9°C)	40	~50	455	Air velocity: 580 ft/min (floor vent) 245 ft/min (over-head vent)
Air Conditioning / Computer Room	General room	22.4°C (72.3°F); 74.2°F (23.4°C)	45	~30	306	
		Folsom Building				
Boiler Room	Chilled water	46°F (7.8°C); 14.4°C (57.9°F)				
	Chilled water return	54°F (12.2°C);				
	Condensate water return	18.7°C (65.7°F)				
	Condensate water supply	32.4°C (90.3°F)				56 psig

Room	Description	Temperature[a]	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	Other
Boiler Room: (York Code-pak Liquid Chilling System)	Motor current					83 (~160 amps)
	Chilled water supply	44.5°F (6.9°C)				
	Chilled water return	51.1°F (10.6°C)				
	Condenser water supply	93.3°F (34.1°C)				
	Condenser water return	89.0°F (31.7°C)				
	Oil pressure					39.3 psi
Boiler Room/ Chilling System	Chiller (before pump)	27.6°C (81.7°F)				76 psig
	Chiller (after pump)	14.8°C (58.6°F)				92 psig
	Pumps	73°C (163.4°F)				385.6 rpm
Boiler Room	Inside room	16.7°C (62.1°F)			551	
	Boiler room wall	27.1°C (80.8oF)				
Data Center	Data Center	23.1°C; 77.5°F	42		492	
Conference Room	Conference Room	78.2°F (25.7°C) 22.8°C (73.0°F) – (filter) 23.3°C (73.9°F) – (wall) 23.6°C (74.5°F) – (damper)		42	642	Air velocity: ~750 ft/min (vent)
Air Handlers	Air handlers	22.0°C (71.6°F)	42.7			
	Condenser water	36.1°C (97.0°F)				
	Water after cooling tower	27.3°C (81.1°F)				

Room	**Description**	**Temperature**[a]	**Relative Humidity (%)**	**Lighting (foot candles)**	**CO_2 (ppm)**	**Other**
Chiller Water System	Chiller water supply Chiller water return	21.2°C (70.2°F) 23.4°C (74.1°F)				
Cooling Tower	Cooling tower Water supply (intake) Water effluent (exit)	~30°C (86oF) 34.0°C (93.2°F) 26.0°C (78.8°F); 79.1°F (26.2°C)			255	
2nd Floor hallway			42	54 (on desk)		
2nd Floor Suite 250 (air handlers)					618	
1st Floor Data Room		78°F (25.6°C)			521	620 ft/min air velocity at vent
Kitchen			40	48		600 ft/min air velocity at vent
Computer Room		70°F (21.1°C)	50			
Generator Room		34.9°C (94.8°F); 82.2°F (27.9°C)		11	627	

Room	Description	Temperature[a]	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	Other
		Lurleen B. Wallace Building				
Boiler Room	General room	27°C	53	14		
	Chiller water supply	53°F; 44.3°F				74 psig
	Chiller water return	45°F; 51.1°F				
	Chilled water supply pump					67 psig
	Incoming condenser water	81.0°F; 28.0°C				
	Exiting condenser water	90°F; 32.0°C				56 psig
	Hot water heaters	124°F; 148°F				
	Condensate pumps					46 psig (inlet)
	Refrigeration on evaporator					12 psig (outlet)
	Refrigeration on condenser					71.2 psig
	Pressure drop on oil					170.6 psig
	Pressure drop on filter					91.4 psig
	Condenser liquid leaving system	88.0°F (31.1°C)				3.6 psig
	Condenser liquid return system	80.3°F (26.8°C)				
	System amperage					A: 240; B: 238; C: 241
	Motor current					
	APB Economizers (entering chilled water return)	58°F (14.4°C)				91%
	Economizers (condenser water)	67°F (19.4°C)				65 psig
Maintenance Shop Drawing Area	General room	23.7°C (74.7°F); 76°F (24.4°C)	47	32	469	

Room	Description	Temperature[a]	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	Other
3rd Floor Air Handlers	Outside air Return air Exhaust air Roof Room	21.8°C (71.2°F) 21.3°C (70.3°F) 21.1°C (70.0°F) 22.2°C (72.0°F) 75.0°F (23.9°C)			525	
3rd Floor Hallway		21°C (69.8°F)	48	32		
3rd Floor Office		22.9°C (73.2°F); 77.1°F (25.1°C)	47	78.4	587	
Conference Room		23°C (73.4°F)	46	70	479	
Office Room			47	78		430 ft/min air velocity at vent
		Capitol Building				
General Maintenance Area	General room	27.5°C (81.5°F) – (ceiling) 82.7°F (28.2°F) – (wall)			469	
Air Handlers	Air handler Hot water supply Hot water return Chilled water supply	21.2°C (70.2°F) 23.4°C (74.1°F) 22.7°C (72.9°F)				

Room	Description	Temperature[a]	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	Other
Computer Room		25°C (77°F)	45	22	442	
		Archives Building				
Old Building Boiler Room	General room		37			240 ft/min air velocity at vent
	Smith cast iron boiler:					
	outer sheet	52.5°C(126.5°F) – (insulated); 97.8°C(208.0°F) – (metal)				~8 psig
	steam sheet	109.5°C(229.1°F)				
	nut on boiler	114°C (237.2°F)				
	flange on boiler	124°C (255.2°F)				
	Weil McLain boiler:	46°C (114.8°F)				
	insulated metal	113.4°C(236.1°F)				
	steam sheet	91°C (195.8°F)				
	metal on boiler	~30°C (86°F)				
	Boiler water supply	60.9-90.5°C (141.6-				
	Condensate return	194.9°F)				
Boiler Room	Trane Turbo-compressor Centravac system:					
	Cold water supply	9-13°C (48.2-55.4°F); 46°F (7.8°C) – (on gage)				
	Condensate supply	84°F (28.9°F) – (on gage)				59 psig (on gage) 25 psig (on gage)

Room	Description	Temperature[a]	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	Other
New Air Handlers	Air handlers	24.4°C (75.9°F)				
	Walls	23.7°C (74.7°F)	38	35	345	
	Air flow chamber	27.7°C (81.9°F)				
Hallway by Air Handlers	Hallway/Room	53°C (127.4°F)		55		
	Hot water return	42°C (107.6°F)				
Conference Area	General room	75.3°F (24.1°C)			396	
		Archives Heating and Refrigeration Building				
Boiler Facility	Chiller water return	46°F (7.8°C)				34 psig
	Chiller water supply	40°F (4.4°C)				27 psig
	Evaporator (entering)	45.0°F (7.2°C)				
	Evaporator (leaving)	38.0°F (3.3°C)				
	Evaporator saturated refrigerant	36.2°F (2.3°C)				
	Evaporator approach	1.7°F (0.9°C)				-9.4 psig
	Condenser (entering)	83.2°F (28.4°C)				
	Condenser (leaving)	90.0°F (32.2°C)				2.5 psig
	Condenser saturation refrigerant	89.9°F (32.2°C)				
	Condenser approach	-0.1°F (-0.1°C)				
Boilers	Boiler No.1	372°F (188.9°C)				70 psig
	Boiler No.2	233°F (111.7°C)				68 psig

Room	Description	Temperature[a]	Relative Humidity (%)	Lighting (foot candles)	CO_2 (ppm)	Other
		State House				
Boiler Room			43	21		
1st Floor Air Handlers	Air handlers	20.9°C (69.6°F) – (walls) 21.6°C (70.9°F) – (entering air)				
2nd Floor Air Handlers	Air handlers	21.0°C (69.8°F) – (wall)	42			
Hallway	Hallway	22.3°C (72.1°F) – (wall) 18.6°C (65.5°F) – (air vent)	47			Air velocity: 330 ft/min (air vent)
Governor's Office			46	21		
House of Representatives Chambers	House of Representatives Chambers	20.6°C (69.1°F) – (walls); 85.4°F (29.7°C)	47	42	382	
Senate Chambers	Senate Chambers	21.7°C (71.1°F) – (walls)	46			
Secretary of State Office	Secretary of State Office	24.0°C (75.2°F) – (wall)				T-8 ballasts/ 3 bulbs/fixture

[a]Readings on temperature gauges reported in °F; temperature measurements taken using an infrared thermometer are reported in °C

The observations for individual building for the Alabama State Capitol Complex are summarized as follows:

Gordon Persons Building: The Gordon Persons Building has 720,000 ft^2 out of which 690,000 ft^2 is leased. In 1989, there were 2.5 acres of floor area. Lighting is controlled on computer. The heating system is a 4 pipe system. The heater is set on the outside perimeter for coils. If there is heat outside, it does not go to inside. There are 38 air handlers in this building. In August 1989, there were roof problems (leaks in the roof). There are small exhausts fans on the roof, along with the cooling tower, and a 20 kW heater. There are some chiller problems. Mr. Lee Snell serves as the building manager.

The boiler is a 250 HP Burnham 3 phase system, Model No. 3L-250-50-60-GP-LB, The air handling system utilizes a Trane Model No CVHE-089g-AQ, 480 V, 60 Hz, equipped with a pneumatic air compressor, and an air handler (filter changed every 4 months). There are two chillers, with always at least one operating at 50 efficiency.

There are four quads or floors. Each zone has its own air intake. The windows remain closed, the windows are double-paned and tinted. The lighting system uses the old mechanical ballasts, although the printing or publication area has the new electrical ballasts. Lights are on or off after hours; 2 to 4 of lights remain on after hours. The lights shut off after 4 hours unless you call in to keep the lights on. The air conditioning is controlled by a computer system. A high temperature above 82^oF (27.8^oC) turns the air conditioning on; a temperature below 68^{o}F (20^{o}C) brings the boiler (heat) on. The computer system also allows the air handlers to be controlled separately; ¼ of the floor can be controlled as a time.

The heating/cooling system, built in 1989, has a 4-pipe system. Heat is generated throughout the year. Variable air volume (VAV) controllers are used. The controllers also use temperature sensors. There are 1369 sensors used for each VAV box. Personal space heaters are discouraged from being used; a space heater costs $100/year/heater.

There are leakage problems with the roof; there are broken core samples and insulation has pulled loose from the walls. The roof is covered with stones in an effort to reflect the heat from the solar radiation. There are tears and holes, and bullet fragments. They have a 20-year warranty on preventative maintenance. Insulation is on the fire side of the boiler. They spend more than $50,000 annually on preventative maintenance (working through ABC). They have the potential to vent the boiler exhaust with the roofing. There are 38 air handlers and 1369 VAVs. There are two cooling towers (one for each chiller) on the roof.

Folsom Building: The Folsom Building has 236,000 ft^2 of floor space. The building was built in 1953. The cooling towers are at the top of the roof (water used for both heating and cooling). The cooling tower is in need of repair. One cooling tower on the roof is planned to be replaced. The Evapco evaporative cooling tower for whole building will be replaced in October 2005 because of leaks. The roof is a 3-ply bonded membrane roof, charcoal grey, which is approximately 3-4 years old. Some offices have variable air volume (VAV) on the air handlers.

Mr. Bill McCoy serves as the heating and air conditioning manager. The project team visited the boiler room (in Room 28C in the basement of the Folsom Building). Water heating service is with Anco Superior. Chemicals used on the boiler water include the following: Anocide 4070 (Anco Company), sodium hydroxide, Ancol 3700. They use city water for operating their boilers and chillers. Chiller had the following identification: YDTJ-76 SN MRP219826. Chiller return temperatures were in the range of 47 to 56^{o}F (8.3 to 13.3^{o}C). Boiler No.2 is still the original boiler installed in the facility. Boiler No.1 was retrofitted last February-April time frame (2004). The boiler and chiller systems were not inspected physically, but their operation was noted during the preliminary audit.

The chiller system (Refrigerant compressor Model No: YDTJ-76) was remodeled in 1987. The system was equipped with temperature sensors, new fan coils (with outside air intake), and new air handlers. The chiller operates 24 hours a day and 7 days a week. There are no real problems with the system. There are EMS pneumatic controllers with digital readout. Chillers were 350 ton chillers, operated at 565 gpm chilled water at 40 ft. They use 75 HP condenser pumps, Bell and Gossett 70 gpm pumps (at 40-ft head) and 15 HP pumps (at 60-ft head) Bell and Gusset pumps, Model No. VSC, BF [chilled water temperatures on the pump casing were 73^{o}C (163.4^{o}F)].

A two pipe distributor requires changing over from heating to cooling (the same piping carries both). The chiller operating noise level was at 87 dB. A spare standard fan coil unit for this building was observed under the stairs and is used on perimeters and spaces.

Steam Generators (Burnham) are 3-pass generator systems. Generators are 100 HP and operate at 3450 lbs steam/hr. The facility was operating all three chillers during the preliminary audit visit. The boilers are used strictly for heating. The hot water heater is used strictly for domestic use.

There are 2 hot water heaters (Rheem commercial hot water heater Model No. RF300-92, 300,000 btu/hr) with a 92 gallon capacity, operating at 61^{o}C (141.8^{o}F); 178^{o}F (81.1^{o}C). Bell & Gusset pump Model No. VSC.

Chiller intake or output at the air handler uses a Trane unit on the south wing of 7th floor. The old Robert Shaw controller can't be upgraded red rubber; they have patched air leaks, but parts are unavailable. They should look on the internet for used equipment dealers.

There are 14 air handlers each serving the south and north wings for 7 floors of the building. In the basement, there are two ducts all involving outside air intake. The air handler mixes outside air with chilled air. The air handler mixes outside air and room return with a locked down damper (at initial balance point); the chiller supplied at 55^{o}F

(12.8^{o}C) to its zone static pressure control (1.5 in W.C.). The building exhaust is through leakage! The boiler vents to the roof through forced draft. Exit temperature (from the basement) is 150 to 160^{o}C (302-320^{o}F) and exit temperatures in the exhaust air ducts on the roof were 25.5^{o}C (77.9^{o}F).

There are 8 floors in the building (including the basement). Fans and thermostats control the temperature in the building. Normal lighting is 8 to 11 foot candles in a room. The rooms had thermo pane windows. Old exit lights were employed.

Data Center: This is the other large energy user in the building. The center operates 24 hours a day, 7 days a week. There are seven heating or humidification or air conditions units in the center. These are 15-ton units, which were put in during 1997. There are 13 units total. The facility maintains 70^{o}F (21.1^{o}C) and 50 relative humidity. They use electric heating and infrared humidification; the floors are also used for ductwork. The generators are dedicated to the data room (computers) and for the data center (air conditioning). This facility could handle the electrical supply for the whole building. Computers constantly monitor system performance 24 hours a day, 7 days a week. The computers do no go to sleep. Heat taken out of the data center (fanned outside the facility) is 42^{o}C (107.6^{o}F).

Fans and thermostats are in the offices. Suite 250 (used for communications and as a data center) and area on 6th floor has its own system (6th floor computer room air conditioning unit is on the roof). The rooftop stairwell is a pressurized system for fire protection. The building has old exit signs.

The roof area is a 3-ply bonded membrane roof, charcoal grey, that is approximately 3-4 years old. There were two expansion tanks for chilled water (6-ft high and 3-ft diameter). The cooling tower has two cells with a common sump and variable speed controlled fans. There were two Trane air conditions units (5 tons each) for the 6th floor of the building. It also serves the computer room. The 7th floor has separate air handlers for each wing and floor area. These air handlers had the following characteristics:

- 7.5 HP
- 430 V
- 3 phase, 60 Hz

There are 14 air handling systems. The outside air mixes with the return air. Measured data collected on the air handling system observed are listed below:

- Outside air: 24.2^{o}C (75.6^{o}F)
- Return air: 24.8^{o}C (76.6^{o}F) @ 1.5-in. water
- Chilled water: 24.3^{o}C (75.7^{o}F); 55^{o}F (12.8^{o}C) on gauge

The computer room has 7 Liebert, 15 ton air conditioning unit with outside condensers installed in 1998. The Liebert condensers are located outside. They use electric heating, infrared light bulb boils water to control humidity within ± 0.5 relative humidity. This heat could be recovered. Cooled air flows through the 14 inch deep removable computer tiled floor 2x2 ft squares. Emergency switch gear energy power can feed the grid which runs every Thursday from 2-4am. They get paid for the electricity generated. The system is 4 years old. The computer and its HVAC are on the backup generator. The rest of the building is not on backup. The generator in Room 2 has Model No. SR-4 Catapiller SN-5VA00610.

Lurleen B. Wallace Building: It was built in 1954. Medicaid is the major occupant of the building. The building was renovated in 1994 has electric heating. There is no recycle in any state buildings. There are two 2 York CodePak liquid chilling systems, Model No. YSDBDAS2CJA. There are Hankinson compressed air dryers (2005 model). The motors used are Hankinson compressed air dryers 2005 model and Lincoln motors Model No. SSD4P15T. Hot water is used for kitchen and domestic purposes, and chilled water is used for cooling of the buildings. There are 5 air handlers per floor, York Model No. CS1133VFC15X11. There are thermostats in the majority of rooms and some have occupant sensors. Ms. Sharon Harris serves as the building manager.

Four elevators were renovated in 1994. The boiler room is similar to that observed in the Folsom Building. It uses a York Codepage Liquid Chilling System, Unit No. YS DB DA52CJA. The Network 8000 controls the chiller bypass. There is a leak (condensation) from the chilled water return line in the surge (purge) tanks overhead. For the two hot water heaters, the insulation is peeling away.

They use a Curtis Climate Control System air compressor. This was not running during the time of the preliminary audit. They also use 2 wall units (Hankinson compressed air dryers).

The building maintains a chiller log for each chiller on a daily basis. The log records the following information: oil pressure; filter pressure; evaporator pressure; condenser pressure; cold water pressure; and condensate water pressure (in and out). There is no economizer present for heat recovery.

The building added two space coolers in the computer room. They use resistive heating by VAV. No boiler is used. The air handlers are stacked on top of each other. They use electric heat in the ceiling vents. There are fine air handlers per floor. Some of the air handlers have pneumatic controls and pneumatic thermostats, while others have preset control. Mayer Electric will be replacing the ballasts. This building recycles aluminum cans.

Capitol Building: It utilizes a computer controlled system. There is no central system. The floor areas are controlled in the building. There are six stories in this building. The air handlers had the Model No. 89817780 TCS113SV2P D AHU5.

There are numerous lights that shine on the Capitols dome. Previously all units were run 24 hours a day, seven days a week. The building manager has reprogrammed the lighting inside the building to be on from 6:00 a.m. until 6:00 p.m. This was initiated

2 years ago. There is 2 hour warm up period prior to when work begins at the Capitol. There are four units (Governor's office, Finance office, Chief of Staff Office, and the Shop area) which continue to operate 24 hours a day, seven days a week.

The building manager has installed a pre-filter top lengthen the filter life on some air handler units. Sensors monitor the pressure drop (ΔP) to sense when the filters need replacement on the air handlers.

Flood lights are used to showcase the dome of the Capitol Building (outside). They use more than 60 flood lights (75W each; GE Model No. 75ER30, 75 w, 130 V) equipped with reflectors for this purpose. They are used to flood the exterior and some interior lights. The use of compact fluorescent lights should be considered. The ballast for the mercury flood lights cost $245 each. There are several energy saver ballasts (34 W lights used).

Exit signs employ 20-W Sylvania lights. The Capitol uses mini-flood lights (indoor spotlights) manufactured by Edison, that have 50-W/570 lumens.

Previously, the water bills at the Capitol averaged $6,500 to $8,000/month. The building manager installed a rain gauge that is coupled with the computer control. By doing so, when the weather is rainy, the computer shuts off the sprinkler system. This approach has reduced the monthly water bills to $1,100. The computer ties in with a "drain can" that is used to regulate the irrigation usage. This has reduced the water usage for irrigation to 110,000 gallons/month versus upwards to 3 million gallons/month prior to employing the rain gauges. Currently, water usage is 225,000 gallons/month with 102,000 gallons/month being used for irrigation. Internal water usage is the difference in these two figures, or 123,000 gallons/month. They also catch the rainwater from the roof for use in irrigation. This is a very good practice.

The building manager would like to control the outside lighting; a timer could be set (e.g., York timers) to accomplish this. Metal arc (metal halide) lamps are used to showcase the outside of the Capitol Building. They use 400-W ground lamps, 175-W incandescent pole lamps, and 500-W porch lights to showcase the Capitol Building. The building manager rewired the porch lights which cost $75 each. Prior to rewiring, the building was blowing about 9 bulbs/week.

The building manager has also installed six small heater or air conditioning units that are controlled by thermostats (at the first floor of the north entrance). The basement maintains the lights being on the hallways, 24 hours a day, and seven days a week. All lights in the Capitol Building remain on 24 hours a day, seven days a week. However, the lights do not really need to be on at night and on weekends. The motion sensors could be installed to activate the lights. The earliest people arrive at work 5:00 a.m. and the latest people leave 6:00 p.m.

A number of the building employees have used space heaters to help heat their offices and there have been several fires that have resulted from their usage. Therefore building manager is discouraging their usage. Personal space heaters are discouraged from being used. A space heater costs $100/year/heater.

Several of the 30-gallons electric hot water heaters Ruud (Model No. PE 2S-30-2) have been replaced with 4-gallon point-of-use hot water heaters (Aniston, Model GL4) that are 93 efficient. They are 3.85 gallon capacity, operating on 1500 W. There were five point-of-use hot water heaters in the building; they cost $139 each. The building manager has also installed auto flush toilets in the building, which has helped save money.

Archives Building: It was built in 1975 and the new wing was added in 2003. The boilers were changed in 1986-1987. The new boiler was added in 2004. The old boiler system is still maintained as backup. The two systems involve a 300 ton Trane system and a 120 ton unit. The cooling tower was built in 1985. The building has 177,000 ft^2 of floor space. The Archives Building has a regular staff of 37, 2-3 service people, and 15-volunteer people. With visitors researchers, attendance can reach 500-600 per day. The building is of a concrete structure, and has single paned glass windows for the new building. Heat is supplied by the building across the street (the boiler facility). The original building was built in 1940. The HVAC system was added in the 1960s. The steam heat is distributed, along with steam and hot water. The Coley wing was added to the building in 1974. The Coley wing is for archival/museum storage. Insulated glass should be installed.

The old building boiler room uses a Rheem Acme packaged chiller, Model No. DHW110. This is a single pass system. The chiller was installed in 1985. The air handler is a Carrier system, Model No. 39AC11D199G4. The 3rd floor has a new Trane M-Series climate changer/air handler Model No. MCCB030UA0A0VA, equipped with a CO_2 sensor. They want to upgrade the HVAC system. They would like to replace the current windows with opaque insulated glass. The public area light area uses compact fluorescent light fixtures; the public area is on the 1st and 2nd floors. There are 29 total fixtures. There is 5 x 4 = 20, 20-inch x 20-inch filters on the air handlers. There is a real potential to install an economizer in this facility to save energy. There are air handlers in the new wing of the Archives Building. They have Johnson Controls. The outside air is controlled on CO_2 sensors. The return air is dampened with CO_2. The system is very well insulated.

Archives Refrigeration and Heating Building: This building provides heat for the Archives Building. There are centrifugal chillers (Trane Centravac water chillers). These use the refrigerant HCFC-123. It has Trane Earth wise Purge. There were halogen gas monitors in the building. The centrifugal chillers were installed and started last summer. They have been in operation for 8 months. You can monitor evaporation, condenser, compressor, motor, purge, ASHRAE chiller log, and historical diagnostics. There are two Burnham 3-pass boilers. The first boiler operated at 372^{o}F (188.9^{o}C) and 70 psig, the second boiler operated at 233^{o}F (111.7^{o}C) and 68 psig. There was some heat recovery present in this facility.

State House: It has eight floors. The State House supplies heating and cooling for the Capitol. The Capitol uses single pane windows. The boiler involved was manufactured by Kewanee Boiler Corporation, Model No. L3S 200 G02060; the motors were 25 HP, 1700 rpm Lincoln A.C. motors. Windows in the building were single paned windows.

The mechanical/electrical room is in Room 20. The boiler is a Classic III boiler, manufactured by Kewanee Boiler Corporation. It is a 1000-ft^2, 200 HP boiler that produces 15 psi steam. The operating temperature was 250^{o}F (121.1^{o}C) [on the gauge], 114^{o}C (237.2^{o}F) using an infrared thermometer. Trane Centravac liquid chillers are used to cool the air. The chilled water was 48^{o}F, and the pressure was 56 psig. Air handlers are in Room 32C. There are three air handlers on each floor.