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Establishment of a Building Audit Procedure and Analysis for the Kansas Department of Transportation Phase 2A: Buildings

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Kansas State University Transportation Center

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Over the past few years, state governments and entities have become concerned with the energy consumption and efficiency of their facilities. An effective manner to identify potential to reduce energy and water consumption and increase building efficiency as well as track the effect of improvements is to establish a facility’s baseline resources use as completed in phase one of Kansas Department of Transportation (KDOT) research program. This baseline information when compared to similar facilities can be used to justify changes to improve the current facility. KDOT has funded a second phase of research that focused on establishing a proper auditing procedure as an additional and more complete method of identifying the areas within their buildings that should be considered for improvement. This second phase of the research not only established a procedure for the audit but also created a list of the most common areas within KDOT owned facilities that may be considered for improvement. This list of recommendations can be used as a starting point but can also be further analyzed for their economic viability using the spreadsheet created to calculate the life cycle costs and return on investments. The audit procedure, as well as the economic spread sheet, was created in a manner that individual facility managers will be able to use them to assess the buildings under their supervision.

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THE KANSAS DEPARTMENT OF TRANSPORTATION
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and

KANSAS STATE UNIVERSITY TRANSPORTATION CENTER
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PREFACE

The Kansas Department of Transportation's (KDOT) Kansas Transportation Research and New-Developments (K-TRAN) Research Program funded this research project. It is an ongoing, cooperative and comprehensive research program addressing transportation needs of the state of Kansas utilizing academic and research resources from KDOT, Kansas State University and the University of Kansas. Transportation professionals in KDOT and the universities jointly develop the projects included in the research program.

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Abstract

Over the past few years, state governments and entities have become concerned with the energy consumption and efficiency of their facilities. An effective manner to identify potential to reduce energy and water consumption and increase building efficiency as well as track the effect of improvements is to establish a facility's baseline resources use as completed in phase one of Kansas Department of Transportation (KDOT) research program. This baseline information when compared to similar facilities can be used to justify changes to improve the current facility. KDOT has funded a second phase of research that focused on establishing a proper auditing procedure as an additional and more complete method of identifying the areas within their buildings that should be considered for improvement. This second phase of the research not only established a procedure for the audit but also created a list of the most common areas within KDOT owned facilities that may be considered for improvement. This list of recommendations can be used as a starting point but can also be further analyzed for their economic viability using the spreadsheet created to calculate the life cycle costs and return on investments. The audit procedure, as well as the economic spread sheet, was created in a manner that individual facility managers will be able to use them to assess the buildings under their supervision.

Acknowledgements

The authors want to acknowledge the Kansas Department of Transportation for funding and supporting the research of this report. Leif Holliday and Peter Carttar’s assistance in accessing the facilities and gathering missing data was instrumental in completing the research for Phase II. The accommodations and aid of the managers - Dale Borger, John Boxberger, Dean Earegood, Wayne Nelson, Gary Simmons, and Robbie Weishaar, and staff of the six audited facilities were invaluable. Lastly, the Phase I student researchers, Ramesh Krishna Sreerama, Vamshi Vemula and Sreedurga Kona, collected all of Phase I utility data, allowing for the successful completion of Phase II.

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Due to file size constraints, the appendices are in a separate file that can be found at http://www.ksdot.org/burmatrres/kdotlib2.asp.

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Chapter 1: Introduction

The Kansas Department of Transportation (KDOT) commissioned the Kansas State University Department of Civil Engineering to conduct research to determine how to reduce energy consumption and energy costs in their facilities throughout the state. Research performed aids in reducing carbon dioxide emissions and energy use of KDOT facilities with the objective of reducing operational energy costs with the implementation of building upgrades and improvements that payback in a time period equal to 20 years. This not only will help the state budget but creates a method for KDOT to meet the requirements of the Department of Energy (DOE) in the present and future.

To best meet the needs of KDOT, the Kansas State University research team completed the following:

- Determined recommended minimum acceptable levels of energy consumption for existing building operation and established design criteria for new facilities concentrating on minimum energy use and compliance with DOE requirements
- Created a building energy audit procedure
- Conducted a series of audits on six KDOT facilities
- Compared audit results and utility data
- Generated a list of areas for potential energy efficiency improvement
- Conducted an economic analysis on upgrade options
- Developed an economic payback spreadsheet for future use by KDOT
- Developed recommended changes for the most commonly encountered and energy consuming specific facility attributes that had a reasonable payback potential relative to the initial investment Estimated the reduction in KDOT's carbon footprint based on recommended changes

The process used, as well as the recommendations that resulted from each of the tasks previously listed is described in the chapters that follow.

This report may be read in its entirety or by section as needed. Chapter 2 focuses on the selection of the minimum acceptable requirements for building design and operation level for KDOT facilities when focused on energy consumption. The requirements of the selected baseline is discussed and established in Chapter 3. Chapter 4 addresses energy audits, including the procedure, summaries of conducted KDOT audits, and recommendations for improvements based on the audits. The Energy Star Portfolio Manager program is discussed in Chapter 5. Chapter 6 concentrates on life-cycle-cost analysis of the proposed recommendations, as well as payback for changes. Carbon footprint reductions as a result of recommended changes are addressed and estimated in Chapter 7. The last chapter, Chapter 8, discusses the recommended changes and how to implement those changes. The appendices provide supportive documents and additional details related to the recommendations contained in the report as well as documents that can be used by facility managers to conduct their own energy audits. Appendix A is a condensed summary of the report with the recommended improvements to reduce energy consumption. Further information on energy audits including a field guide to energy audits, the audit worksheet, and a tool guide is addressed in Appendix B. Appendix C contains the audit data collected for the KDOT facilities assessed in this report. Appendix D walks through how to use the Energy Star Portfolio Manager. Lastly, Appendix E is comprised of example calculations performed for the life-cycle-cost analysis for all recommended improvements. Depending on the level of understanding needed the reader may elect to read this report in the order presented or may choose to jump only to those specific chapters needed to address particular issues.

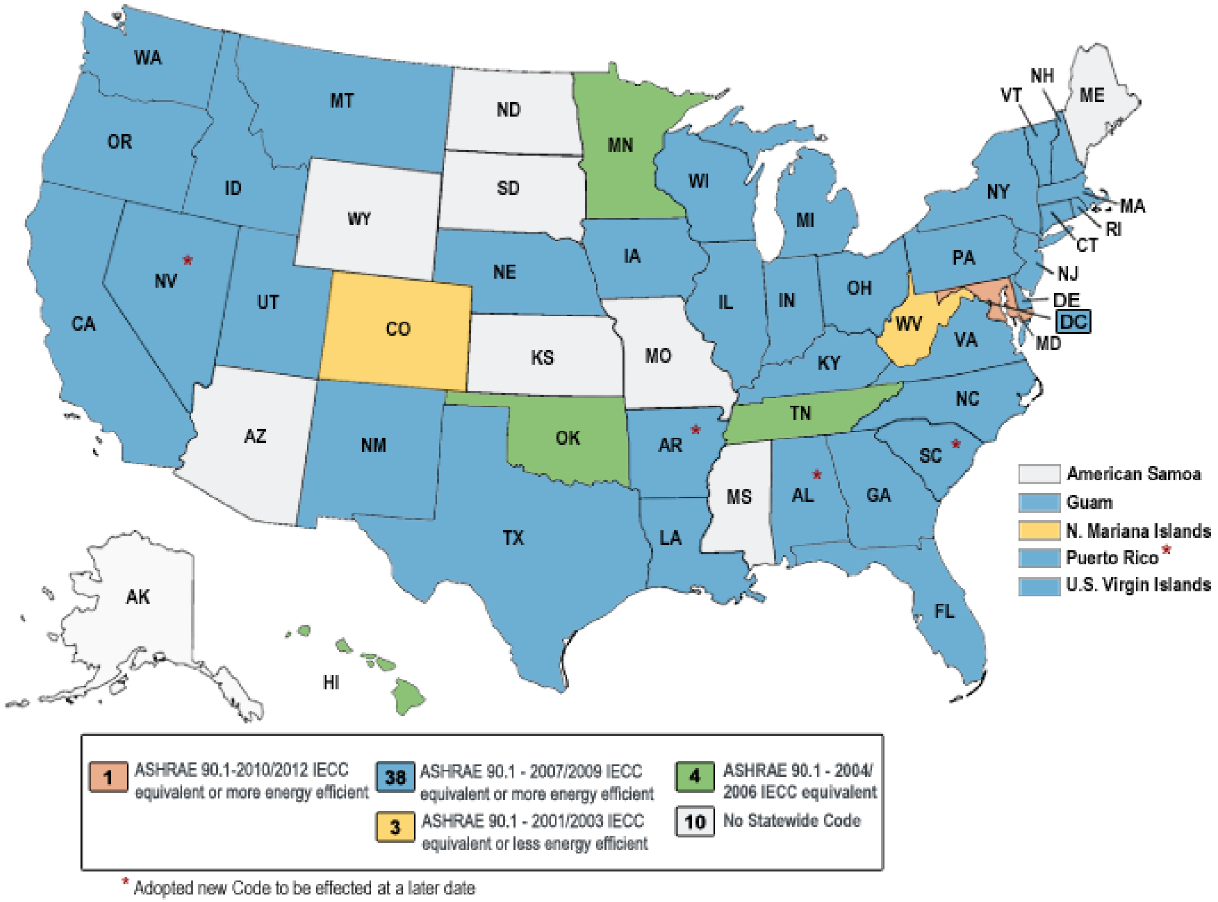
Chapter 2: Selection of the Minimum Acceptable Requirements for Energy Design/Operational Level for KDOT

The first task in conducting the analysis of KDOT facilities was to research and determine the most appropriate energy standard to be used in the recommendations related to upgrades of existing facilities. Selection of an energy standard not only establishes the minimum accepted level of construction and operation of existing facilities but serves as a basis of design for new facilities as energy savings become a greater priority and federal regulations, in the form of Department of Energy Determinations, need to be met. A comparison between the existing building conditions and the selected minimum level extracted from the content of an industry accepted energy standard was a critical step in this research. This comparison identified changes that could be considered to reduce energy consumption. Selecting an industry accepted and supported energy standard ensures that the content is vetted, regularly used, reviewed, and updated by others, minimizing the risk of implementation and effort needed to stay current in the future. To find the best and most applicable energy standard for this comparison two primary factors were considered. First a review of the states surrounding Kansas and their adopted energy standards was conducted. The states considered include Arkansas, Colorado, Illinois, Iowa, Missouri, Nebraska, Oklahoma, and Texas. The intent of this review was to determine what was considered acceptable by peer or neighboring states with similar climates and expectations. This was considered important for this review as certain states, such as California, are known to be much more aggressive than others on the topic of energy use and these states did not necessarily need to be included in this comparison. The second factor considered was the recommendations made by the DOE in regard to published energy standards. The following subsections will identify and discuss the industry accepted energy standards and further explain the decision-making process in selecting a recommended energy standard that could be used as the minimally accepted construction and operational level for KDOT buildings.

2.1 Accepted Energy Codes

Using an existing energy standard as the basis for recommendations in this report allows for well-defined requirements that are industry accepted and understood. The two most prominent energy efficiency codes in the United States are the International Energy Conservation Code (IECC) published and maintained by the International Code Council (ICC) and the ANSI/ASHRAE/IES Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings (ASHRAE 90.1). In addition to these two base energy codes, there are references available that focus on high performance and green/sustainable design. The ICC publishes the International Green Construction Code (IGCC), and ASHRAE publishes Standard 189.1 Standard for the Design of High-Performance, Green Buildings (ASHRAE 189.1). Neither the IGCC nor ASHRAE 189.1 were selected or considered because they were only recently introduced and very few jurisdictions have adopted them. KDOT may reference these documents in the future in order to achieve energy savings above that provided by the IECC or ASHRAE Standard 90.1.

The DOE recognizes both the IECC and ASHRAE Standard 90.1 references as acceptable energy codes. Energy codes are adopted on a state-by-state basis, even though the DOE has established minimums that the states must adhere to by established dates. Figure 2.1, below, depicts the current state adopted energy codes for commercial construction, as updated and provided on the DOE website on June 1, 2012.



(Source: Department of Energy 2012)

FIGURE 2.1
Status of State Commercial Energy Code Adoption

The IECC, as with most of the International Code Series, is predominantly referenced by code officials whereas ASHRAE Standard 90.1 is more familiar to those in a design capacity. Both of the codes have very similar content (building envelope, heating, cooling, ventilation, service water heating, power, and lighting) and many of the same people are involved in their development. IECC specifically states in Chapter 5 – Commercial Energy Efficiency that compliance can be achieved with design meeting the requirements of ASHRAE Standard 90.1. Because ASHRAE Standard 90.1 is more universal and can meet the IECC, it will be used as the minimum level of acceptable construction and operation for this report.

ASHRAE Standard 90.1 provides the minimum requirements for the energy-efficient design of most buildings and offers, in detail, the minimum energy-efficient requirements for the design and construction of new buildings and their systems, new portions of buildings and their systems, and new systems and equipment in existing buildings as well as the criteria for determining compliance with these requirements (ASHRAE, 2010). ASHRAE publishes a revised version of the standard every three years, continually increasing the stringency of the requirements to reduce energy consumption and increase efficiency (ASHRAE, 2010). The most current version of ASHRAE Standard 90.1 is 2010 with a new version planned to be published in 2013. Using the 2010 version, as opposed to earlier versions, is an especially appropriate choice for this report because the DOE has issued mandates, also known as determinations, to push the building industry towards energy efficient design and utilization. Determinations establish requirements that must be met by a stated time. On July 20, 2011, DOE issued a determination that ASHRAE Standard 90.1-2007 would achieve greater energy efficiency in buildings subject to the code, than the 2004 edition and all states had two years to adopt ASHRAE Standard 90.1-2007 or upgrade their existing commercial building codes to meet or exceed its requirements (Department of Energy 2011a). However, on October 19, 2011, DOE issued a final determination that ASHRAE Standard 90.1-2010 would achieve greater energy efficiency in buildings subject to the standard than the 2007 edition (Department of Energy 2011a). This final determination was published before the two-year deadline to file a certification for the 2007 positive determination; therefore, a state may file just one certification to address both determinations (Department of Energy 2011a). The certification must include a demonstration that the provisions of the state's commercial building energy code regarding energy efficiency meet or exceed ASHRAE Standard 90.1–2010 and be filed by July 20, 2013 (Department of Energy 2011a). All states have two years to adopt ASHRAE Standard 90.1-2010 or upgrade their existing commercial building codes to meet or exceed its requirements (Department of Energy 2011a). Therefore, the 2010 edition of the standard will serve as the minimum construction and performance criteria for this report.

Many jurisdictions did not adopt the ASHRAE Standard 90.1-2007 because of the very minor changes between it and the 2004 version as well as the anticipation there would be significant changes in the 2010 version. The energy savings between ASHRAE Standard 90.1-

2004 and -2007 was only 5%, whereas the energy savings between ASHRAE Standard 90.1-2004 and -2010 is 30% (The Energy Systems Laboratory).

2.2 Surrounding State Energy Codes

As previously discussed, the codes of surrounding states were also reviewed and considered. Table 2.1 states the codes for each state considered, both for commercial construction and state-funded construction (Department of Energy 2011a). The graphic in Figure 2.2 depicts the status of energy codes for the surrounding states considered (Department of Energy 2011a). The graphic and the table show the energy code that is adopted, even though the code may not be enforced.

TABLE 2.1
Adopted Energy Codes for Kansas and Surrounding States as of June, 2012

State	Adopted Commercial Energy Code	Adopted State-Funded Energy Code
Kansas	ASHRAE Standard 90.1-2004/2006 IECC	None
Arkansas	ASHRAE Standard 90.1-2001/2003 IECC	10% Better than ASHRAE Standard 90.1-2007
Colorado	ASHRAE Standard 90.1-2001/2003 IECC	LEED Certification
Illinois	ASHRAE Standard 90.1-2007/2009 IECC	LEED or Green Globes Certification
Iowa	ASHRAE Standard 90.1-2007/2009 IECC	Energy Reductions Beyond 90.1
Missouri	None	ASHRAE Standard 90.1-2004/IECC 2006
Nebraska	ASHRAE Standard 90.1-2007/2009 IECC	No additional requirements
Oklahoma	ASHRAE Standard 90.1-2004/2006 IECC	LEED or Green Globes Certification
Texas	ASHRAE Standard 90.1-2007/2009 IECC	No additional requirements

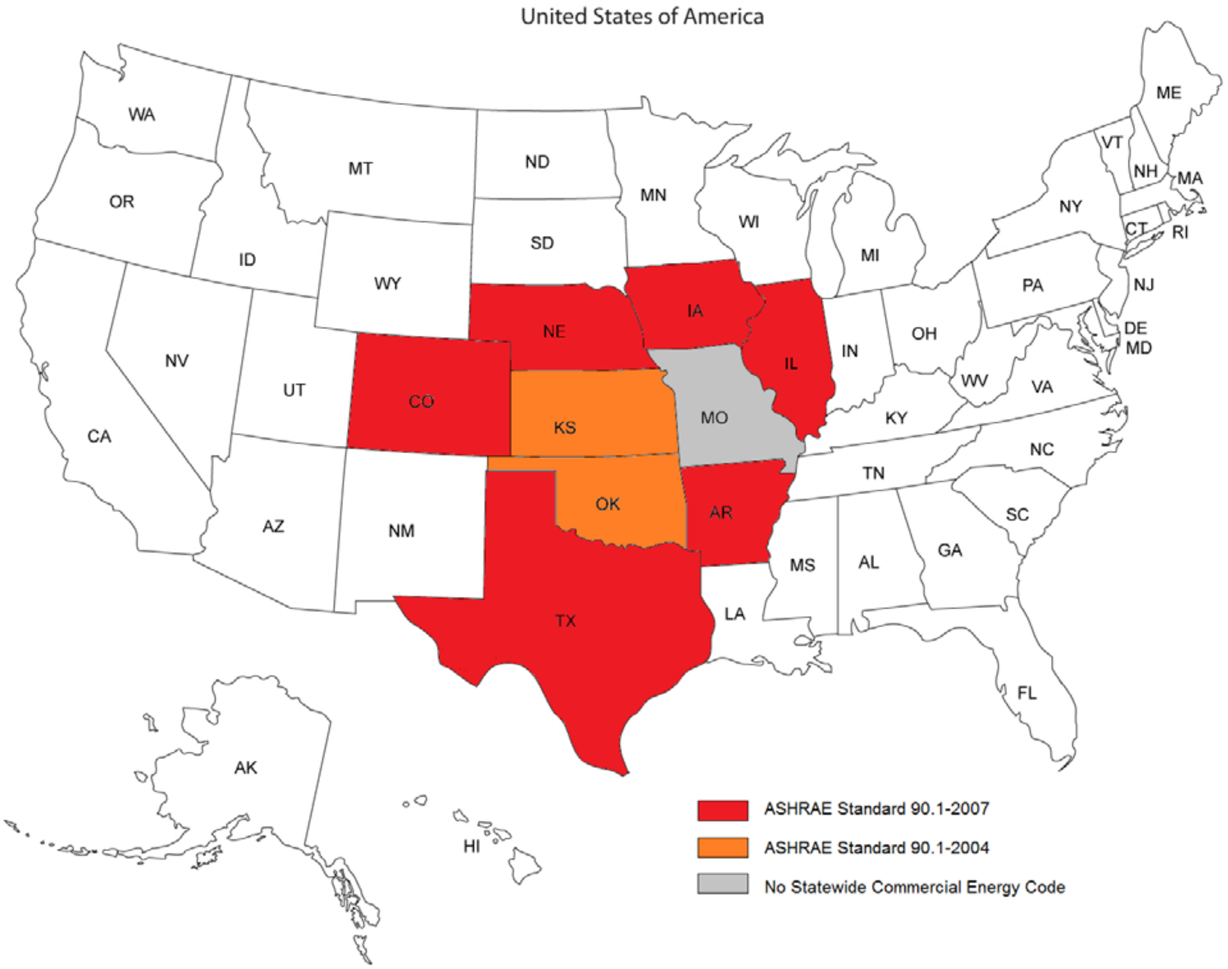


FIGURE 2.2
Status of Energy Codes for Surrounding State Commercial Buildings

Currently, Kansas has adopted 2006 IECC as the statewide commercial code which accepts ASHRAE Standard 90.1-2004 as an alternate compliance path; however, the state does not enforce the code, nor does it have a way to govern if the codes are complied with (Department of Energy 2012). There are no established energy requirements for state owned or funded facilities (Department of Energy 2012). The state of Kansas is less stringent than surrounding states, especially in regard to state funded facilities. Arkansas has established ASHRAE Standard 90.1-2001/2003 IECC as the minimum for commercial buildings, with state-owned or -funded new or majorly renovated buildings required to be 10% better than ASHRAE Standard 90.1-2007 (Department of Energy 2012). Colorado requires commercial buildings to meet ASHRAE Standard 90.1-2001/2003 IECC, while state owned or funded buildings must conform to a state High Performance Certification Program or a Leadership in Energy and Environmental Design (LEED) certification, which is at least 25% better than the ASHRAE Standard 90.1-2007 requirements (Department of Energy 2012; Lui 2008). The state of Illinois has adopted ASHRAE Standard 90.1-2007/2009 IECC for commercial buildings and requires LEED or Green Globes certification for state-funded facilities (Department of Energy 2012). Iowa requires commercial buildings to meet ASHRAE Standard 90.1-2007/2009 IECC, whereas state owned or funded buildings must meet staged energy reductions as set forth by the state of Iowa (Department of Energy 2012). The bordering state of Missouri, has no statewide commercial code, but does require new construction of state-owned or -funded projects to meet the 2006 IECC if the construction project is larger than 5,000 square feet and also requires a 25-year life-cycle-cost to be calculated (Department of Energy 2012). Nebraska has adopted ASHRAE Standard 90.1-2007/2009 IECC as the state's commercial energy code, with no separate requirements for state-owned or -funded facilities (Department of Energy 2012). Even though Oklahoma has adopted the IECC 2006 as the statewide commercial code, it requires state-owned or -funded buildings over 10,000 square feet to follow LEED guidelines or Green Globes (Department of Energy 2012). Lastly, Texas established ASHRAE Standard 90.1-2007/2009 IECC as the minimum for commercial buildings as well as state-owned or -funded buildings (Department of Energy 2012).

Based on the comparison to surrounding states, it is appropriate to increase the stringency of the construction and operation of state funded facilities in Kansas. The recommended minimum standard will be further discussed in Chapter 3. Although some states require that building certification be part of minimum requirement set for the state funded facilities, it is not the recommendation of this report because of the added expense that is incurred in the certification process.

Chapter 3: Minimum Construction and Operational Requirements for New Facilities and Renovations

ASHRAE Standard 90.1-2010 should be used as the design minimum for all KDOT facilities. The standard establishes minimum requirements for both new facilities and renovations to existing facilities. In order to improve energy efficiency in KDOT facilities, the requirements defined by ASHRAE Standard 90.1-2010 should be consulted and followed for any project. It is recommended that KDOT establish one contact person who is knowledgeable and understands ASHRAE Standard 90.1-2010 and will serve as the facilitator of renovations and construction of new facilities. This person will ensure that KDOT facilities are meeting the requirements of ASHRAE Standard-90.1-2010 and avoiding penalties, such as fines, from the state or federal government. As energy codes continue to advance and newer editions are published, KDOT should consider adopting the most current code when introduced to ensure future progress.

ASHRAE Standard 90.1-2010 addresses energy efficiency requirements for all building aspects, from the building envelope to the specific building systems. The standard is applicable to all buildings except for low-rise residential, with sections tailored to varying building classifications (ASHRAE 2010). A majority of KDOT facilities fall under the classification of a ‘simplified building’. As defined in ASHRAE Standard 90.1-2010, a simplified building is, “two stories or fewer in height and gross floor area is less than 25,000 square feet” (ASHRAE 2010).

Renovations to existing KDOT facilities have requirements established by the baseline of ASHRAE Standard 90.1. According to ASHRAE Standard 90.1, when an addition is added or alterations are made to a facility, the changes must comply with the requirements of the standard (ASHRAE 2010). In making changes to existing facilities, the baseline of ASHRAE Standard 90.1 must be consulted in order to ensure that the changes improve the energy efficiency of the facility. To know when the requirements of ASHRAE Standard 90.1-2010 are applicable, see subsection 4.2 Compliance Paths within ASHRAE Standard 90.1-2010 (ASHRAE 2010).

For simplicity and clarity, this report will only address simplified buildings. For all construction that does not meet the simplified building requirement, ASHRAE Standard 90.1-2010 will need to be consulted in its entirety. Table 3.1 displays the sections of ASHRAE Standard 90.1 that need to be consulted when designing a new simplified building, with discussion about the sections' content following the table. The minimums established in the sections of ASHRAE Standard 90.1-2010 only apply to new construction, additions, or significant renovations when adopted, but for the purposes of this report it is suggested that these minimums also be considered as the baseline for improvements to existing facilities.

TABLE 3.1
Applicable Sections of ASHRAE Standard 90.1-2010 for Simplified Buildings

Section Number	Section Title
5.4	Mandatory Provisions for Building Envelope
6.3	Simplified Approach Option for HVAC Systems
7.4	Mandatory Provisions for Service Water Heating
8.1.2	Low Voltage Dry-Type Distribution Transformers
8.4	Mandatory Provisions for Power
9.4	Mandatory Provisions for Lighting
Normative Appendix B	Climate Zones

ASHRAE Standard 90.1-2010 Section 5 addresses the building envelope (ASHRAE 2010). For this section, it is imperative to know the type of spaces being designed and how they are thermally conditioned. Most KDOT facilities will feature two types of conditioning; nonresidential conditioned, referring to the office areas, and semiheated, referring to the enclosed garages (ASHRAE 2010). Subsection 5.4 addresses the requirements for insulation, as well as maximum areas allowed for fenestration and doors (ASHRAE 2010). This section also addresses the requirements to reduce air leakage, such as vapor barriers, caulking and sealing (ASHRAE 2010). By adhering to the conditions of chapter 5, heat loss and gains can be reduced in the building (ASHRAE 2010).

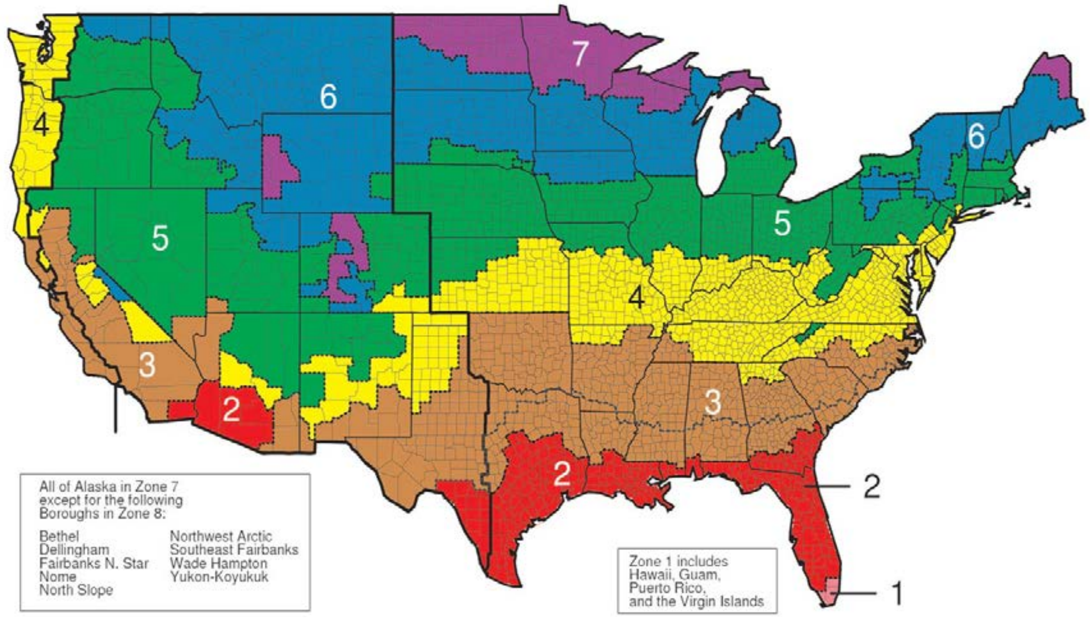
Section 6 of ASHRAE Standard 90.1-2010 focuses on the building's heating, ventilating, and air-conditioning (HVAC) system(s) (ASHRAE 2010). The simplified approach, subsection 6.3, addresses all requirements of the HVAC system for the simplified buildings typical of KDOT (ASHRAE 2010). Subsection 6.3 states the requirements, efficiencies, and criteria for types of systems utilized, as well as controls for the system (ASHRAE 2010). This section also establishes efficiency requirements for HVAC equipment and minimum insulation requirements for ductwork (ASHRAE 2010). Compliance with the requirements subsection 6.3 allows for the design of an efficient HVAC system and controls, thereby reducing energy costs and life-cycle-costs.

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

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

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

ASHRAE Standard 90.1-2010 Normative Appendix B, deals with climate zones for the United States (ASHRAE 2010). Figure 3.1 shows the different climate zones for the continental United States. The climate zone is based on location and county with specific counties listed in ASHRAE Standard 90.1-2012 Appendix B, Table B-1.The state of Kansas falls into two different climate zones, Zone 4 and Zone 5 depending on the specific county (ASHRAE 2010). Figure 3.2 shows more clearly how the counties are divided between climate zones. The climate zones are broken down even further into moisture categories represented by letters; however, Kansas is either 4A or 5A because it is classified as a moist climate (ASHRAE 2010). Climate zones are referenced throughout ASHRAE Standard 90.1-2010, with requirements varying based on which climate zone a project is located within. The requirements for the building envelope are one example of requirements varying based on climate zone (ASHRAE 2010).



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(Source: ASHRAE 2010)

FIGURE 3.1
ASHRAE Climate Zones for the Continental United States

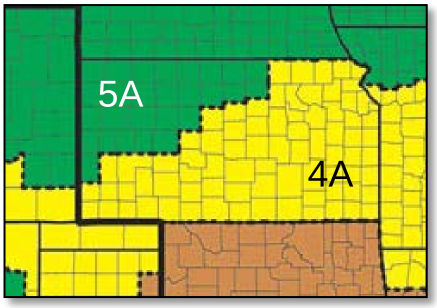

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FIGURE 3.2
ASHRAE Climate Zones for the State of Kansas

ASHRAE Standard 90.1-2010 establishes requirements for new and renovated facilities, which would also be applicable to KDOT facilities. While a majority of KDOT facilities will fall into the definition of a simplified building and therefore having simpler requirements, ASHRAE Standard 90.1-2010 should be consulted for all types of facilities. By adhering to ASHRAE Standard 90.1-2010 for all facilities, energy consumption will decrease and energy efficiency will increase.

Chapter 4: Energy Audits

Energy audits are an essential component to increasing energy efficiency in buildings. Primarily, energy audits serve the purpose of identifying energy uses among the various services within a building and depicting opportunities for energy conservation measures. The goal is to reduce energy use in areas where energy is being wasted and in areas where a reduction will not cause disruptions to the building or occupant functions. Energy audits focus upon all systems and components within a building, including building equipment operation, building envelope, mechanical systems, lighting systems, electrical systems, and water systems.

It is imperative to have an energy audit procedure, customized for KDOT, to allow for consistent and determinative energy audits. With a tailored energy audit procedure, six selected KDOT facilities were examined to determine recommendations for improvements. From the audit results of the KDOT facilities, a list of improvements was developed that have the potential to reduce energy consumption and increase efficiency in not only these six facilities but applied to all 157 KDOT facilities. The following subsections describe in detail the audit procedure, the six facilities visited, and the audit data collected.

4.1 Energy Audits Procedure

Energy audits provide valuable information as to the current conditions of a facility and improvements that can be made to increase efficiency. ASHRAE's "Procedures for Commercial Building Energy Audits", introduces three different levels of energy audits (ASHRAE 2011). In order to best suit KDOT facilities, a custom audit procedure was created by combining applicable components of the three ASHRAE procedures. To best respond to the current and future needs of KDOT, the custom procedure allows for a great amount of details to be gathered in a simplistic manner. There are three main sections to the KDOT audit procedure, 1) Pre-audit, 2) Audit and 3) Post-audit. The three sections are described in detail later in this section. The energy audit documents and the step-by-step audit procedure are located in Appendix B.

Specific tasks need to be completed prior to the energy audit in order to be successful. The pre-audit starts two weeks prior to audit, beginning by sending the owner survey to the facility contact person. The survey responses are needed at least two days prior to the audit. Once the survey is returned, the audit documents need to be updated to reflect the answers on the owner survey. Prior to conducting the onsite inspection portion of the audit, it is best to fill out as much of the audit spreadsheets found in Appendix B as possible using the owner survey and, if available, building floor plans. It is important to become familiar with the floor plans and develop a list of questions for the owner prior to the audit. These questions are different from those asked on the owner survey and are formed when discrepancies are found on the floor plans, or utility bills, or probing questions that only the facility contact could answer. Lastly, all of the equipment needed for the audit should be assembled. The following items should be packed and readily available during the audit: Flashlight, digital camera, yardstick(s), infrared camera, 4-in-1 device(s)—thermometer, light meter, hygrometer, anemometer, highlighters, floor plans, clipboards, writing utensils, and blower door test. See Appendix B, "Tool Guide with Photos" for examples of each item and what they are to be used for during the audit.

The procedure used for the most effective and informative energy audits must be consistent over time and between different facilities; therefore a defined procedure should be adhered to. Firstly, once at the facility, meet with the owner, representative, or contact person and discuss the audit, ask previously-developed questions and take a brief tour of the facility. With the audit worksheet in hand, begin completing the necessary information one room at a time. Be sure to take notes and photos of everything while working through the audit. After all information has been recorded in the interior, and exterior assessment is needed. Walk around the structure, taking notes of any irregularities, and taking digital and thermal photos of the exterior. Lastly, develop exit questions for the owner, representative, or contact person. Ask about anything that was unclear or needed greater description.

After the audit, 'post-audit', compile data in the audit documents. If there are any omissions, be sure to ask the facility point of contact for clarification or information.

4.2 Kansas Department of Transportation Facility Audits

Six KDOT facilities were audited with the purpose of providing a snapshot of building conditions from each KDOT District within Kansas. The facilities were selected based on many factors including similarities in building size and usage, age of facility, renovation timeline, complete utility usage data, and clear and readable floor plans. By choosing facilities with similar floor plans, the data collected could more effectively be compared and more substantive recommendations could be made. The buildings chosen were limited to substations because there are 88 substations that comprise 72% of the KDOT buildings, therefore allowing the data collected and result analysis to have the greatest potential for energy savings impact. The selected facilities are shown in Figure 4.1.

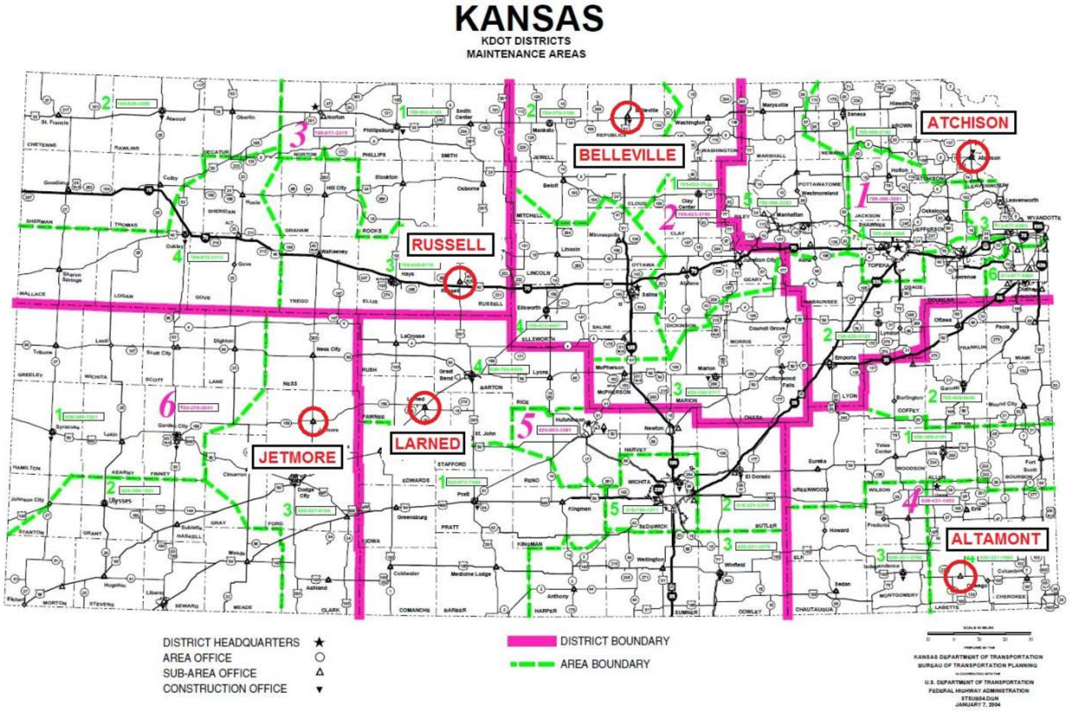

FIGURE 4.1
Map of Selected KDOT Facilities

Atchison, Altamont, Belleville, Jetmore, Larned, and Russell comprised the six selected KDOT facilities. A synopsis of each facility audited is provided in the following subsections. The energy consumption is calculated and displayed per the area of the office space. The office spaces are a larger consumer of energy year round, in comparison to the storage area, and provide an accurate representation of the energy consumption.

In addition to completing the audit as outlined in section 4.1, a blower door test was conducted at the KDOT facilities to identify areas of infiltration and air leakage. A blower door test is conducted by creating a building pressure of 50 Pascal (Minneapolis). A 50 Pascal pressure is roughly equivalent to the pressure generated by a 20-mph wind blowing on the building from all directions (Minneapolis). The blower door fan creates an airflow of 50 cubic feet per minute (CFM), which is the most commonly used measure of building airtightness and gives a quick indication of the total air leakage in the building envelope (Minneapolis). The test is not included in the audit procedure since it is unlikely that KDOT will have the proper equipment and trained personnel to administer the test.

4.2.1 Atchison

In District 1, the facility in Atchison was audited. This facility is denoted by KDOT as District 1, Area 1, Complex 4. This facility, built in 1957, has an office area of 4,277 square feet and a storage area of 2,980 square feet. The Atchison subarea consists of two heated bays, four unheated bays, interior office space, a washbay, and exterior storage. Specifically, the facility features single-pane windows, two natural gas furnaces, a 30-gallon natural gas water heater, natural gas radiant heaters, and T12 and incandescent lamps throughout. Figures 4.2, 4.3, and 4.4 are graphs illustrating the utility usage for Atchison. The blower door test resulted in an infiltration airflow of 5592 CFM. However, the test never reached 50 Pascal and had to be run in open configuration since the door from the office area to the bays had a vent. The blower door test was also pulling in air from the bays, which was different than any of the other facilities.

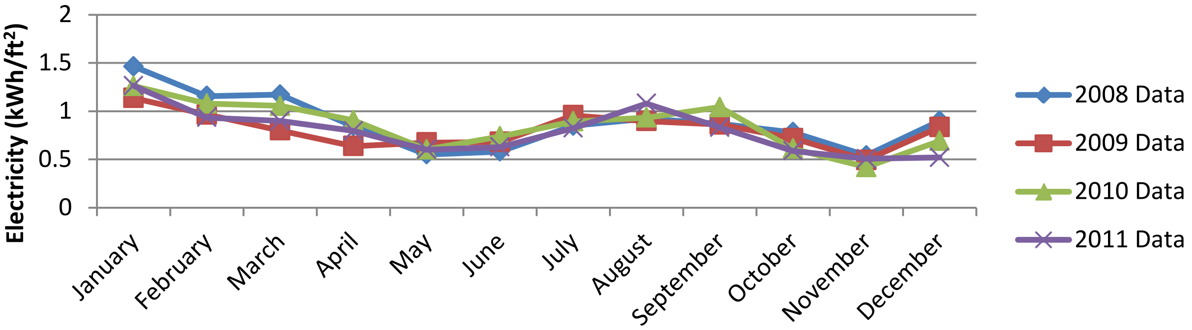

FIGURE 4.2
Electricity Use for Atchison

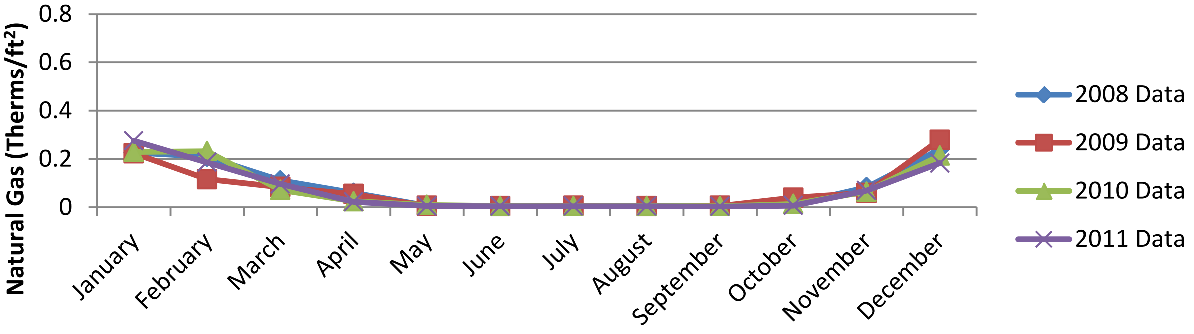

FIGURE 4.3
Natural Gas Use for Atchison

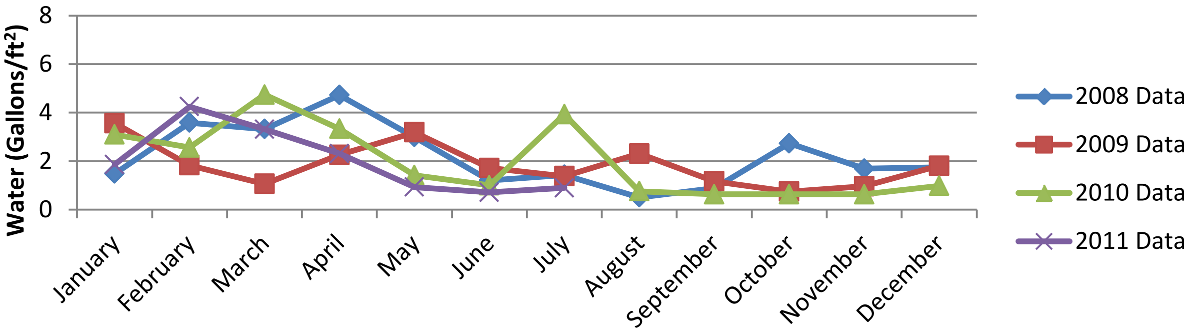

FIGURE 4.4
Water Use for Atchison

4.2.2 Belleville

The subarea in Belleville was selected as the representative for District 2. District 2, Area 2, Complex 59 denotes this facility. The building, constructed in 1963, has an office area of 4,203 square feet and a storage area of 3,027 square feet. The Belleville subarea has two heated bays, four unheated bays, interior office space, a washbay, and exterior storage. Equipment in the facility consists of double-pane windows, a natural gas furnace, an eight-gallon electric water heater, natural gas radiant heaters, and T8 and incandescent lamps throughout. The facility had all windows replaced in 2006. Graphs showing the utility usage for the Belleville facility are Figures 4.5, 4.6, and 4.7. The blower door test for Bellville resulted in an infiltration airflow of 2046 CFM.

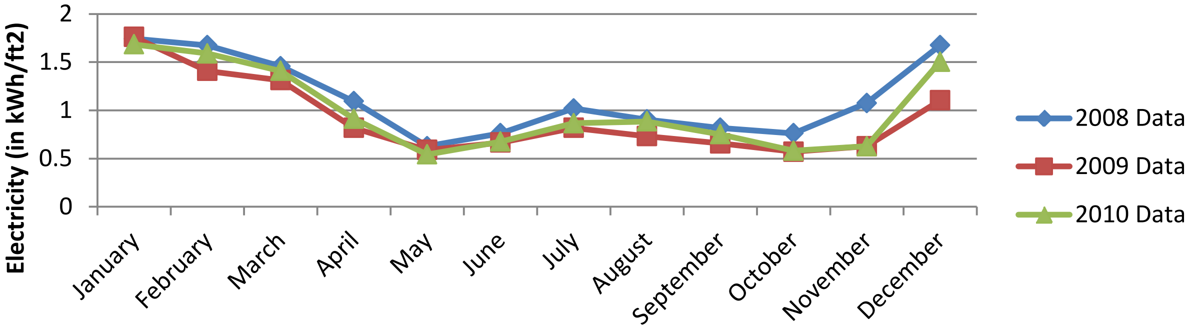

FIGURE 4.5
Electricity Use for Belleville

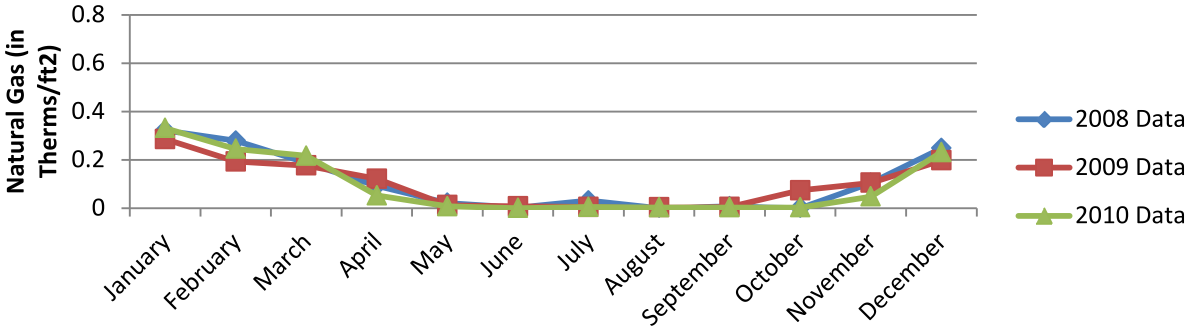

FIGURE 4.6
Natural Gas for Belleville

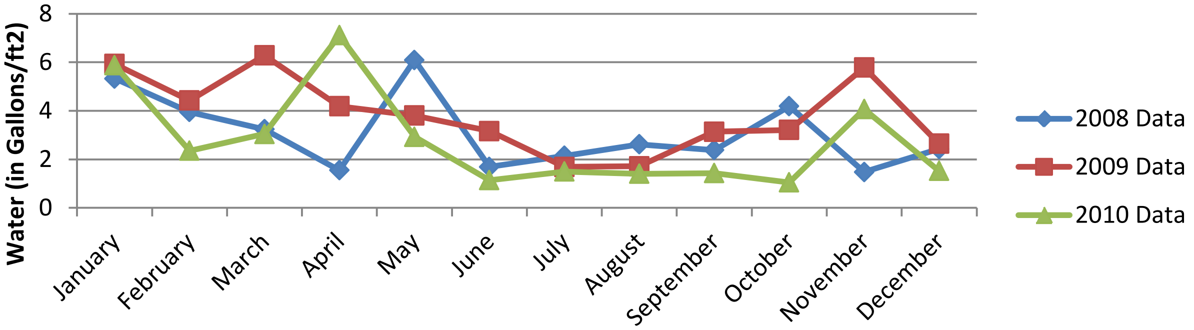

FIGURE 4.7
Water Use for Belleville

4.2.3 Russell

From District 3, the Russell subarea, District 3, Area 3, Complex 91, was selected. This facility, built in 1961, has an office area of 4,138 square feet and a storage area of 2,986 square feet. Two heated bays, four unheated bays, interior office space, a washbay, and exterior storage make up the Russell complex. Russell features double-pane windows, a natural gas furnace, a 29-gallon natural gas water heater, natural gas radiant heaters, and primarily T5HO (High Output) lamps throughout. The three figures, 4.8, 4.9, and 4.10, depict the utility use for the Russell facility. The blower door test resulted in an infiltration airflow of 2330 CFM.

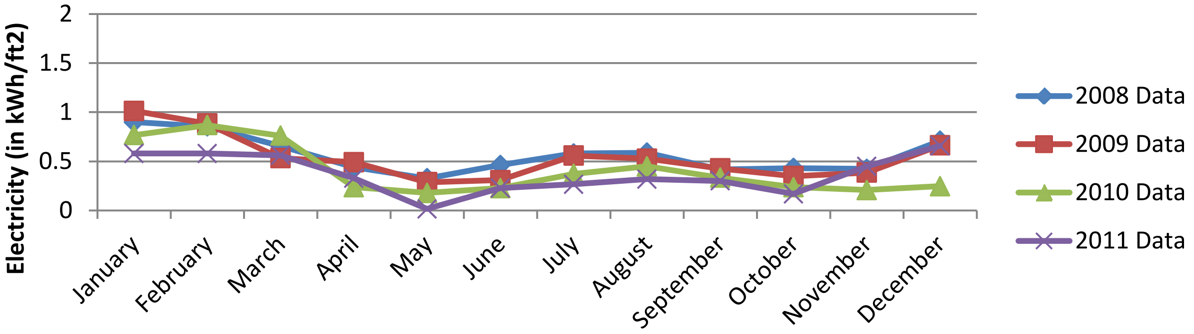

FIGURE 4.8
Electricity Use for Russell

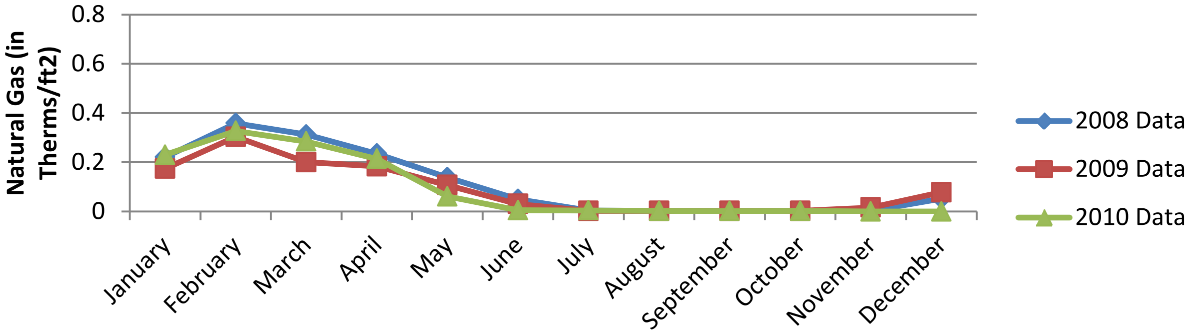

FIGURE 4.9
Natural Gas Use for Russell

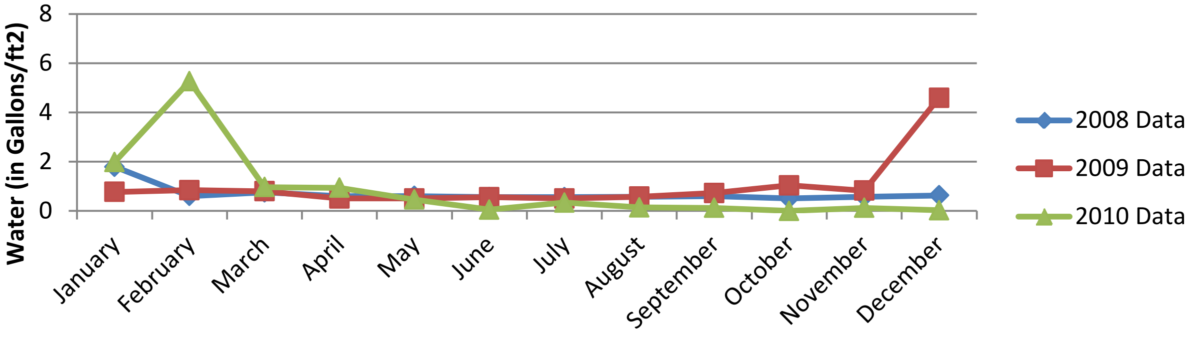

FIGURE 4.10
Water Use for Russell

4.2.4 Altamont

The Altamont subarea, District 4, Area 4, Complex 137, was audited as the District 4 facility. The facility, built in 1966 and renovated in May 2009, has an office area of 2,431 square feet and a storage area of 1,755 square feet. Four heated bays, two interior offices, a washbay, and exterior storage make up the Altamont subarea. The facility features double-pane windows, packaged through the wall air conditioning units with electric heating coils, a six-gallon electric water heater, natural gas radiant heaters, and T8 lamps utilized throughout. Electricity, natural gas and water utility use is illustrated in figures 4.11, 4.12, and 4.13. The blower door for Altamont resulted in an infiltration airflow 1066 CFM.

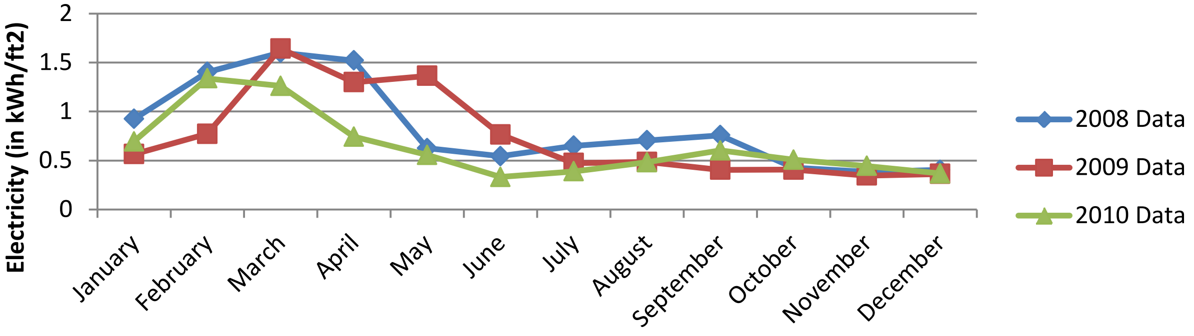

FIGURE 4.11
Electricity Use for Altamont

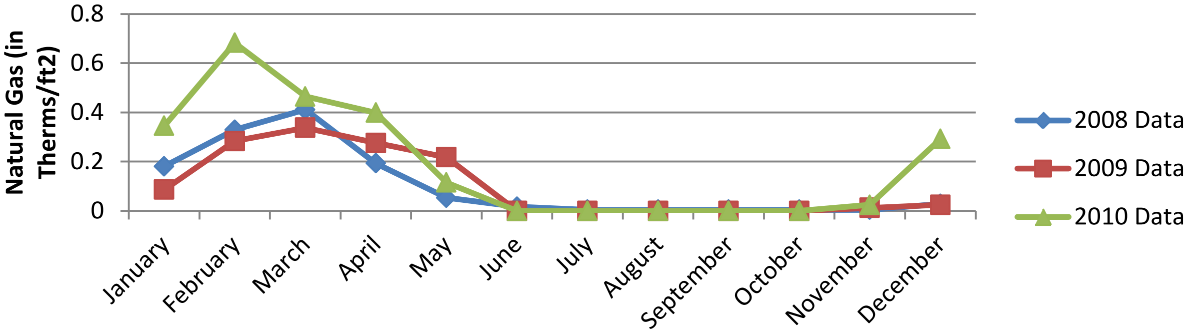

FIGURE 4.12
Natural Gas Use for Altamont

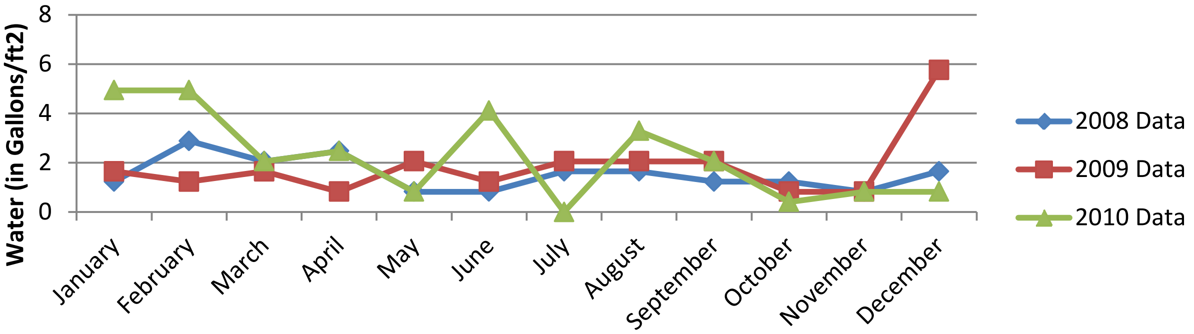

FIGURE 4.13
Water Use for Altamont

4.2.5 Larned

From District 5, the Larned subarea, District 5, Area 4, Complex 130, was selected to be audited. This facility, built in 1961, has an office area of 4,024 square feet and a storage area of 3,067 square feet. The Larned subarea features two heated bays, four unheated bays, interior office space, a washbay, and exterior storage. The facility also has double-pane windows, a natural gas furnace, a 40-gallon natural gas water heater, natural gas radiant heaters, and T12, T5, and incandescent lamps. The utility use is represented in figures 4.14, 4.15, and 4.16. The blower door test resulted in an infiltration airflow 1762 CFM.

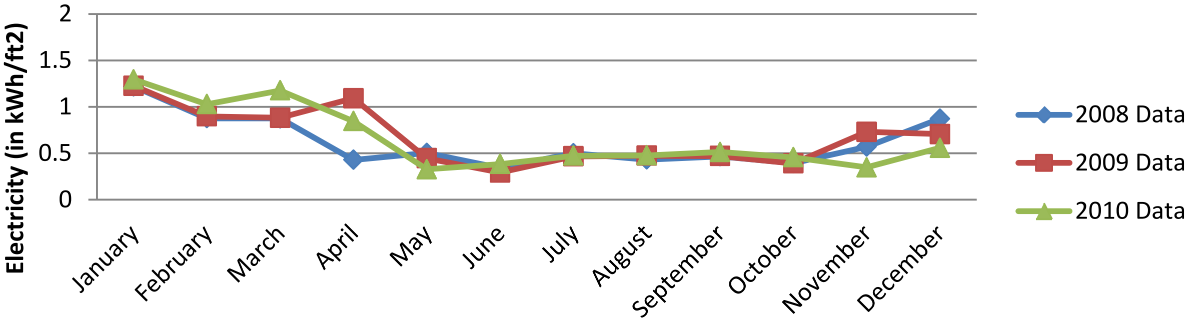

FIGURE 4.14
Electricity Use for Larned

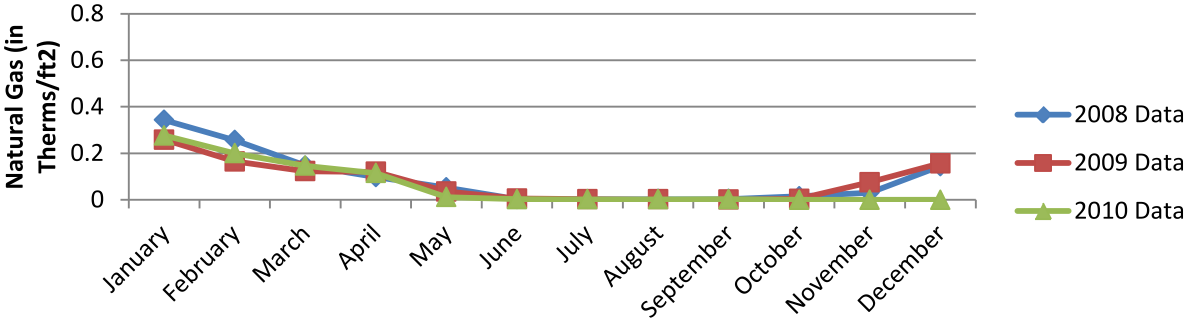

FIGURE 4.15
Natural Gas for Larned

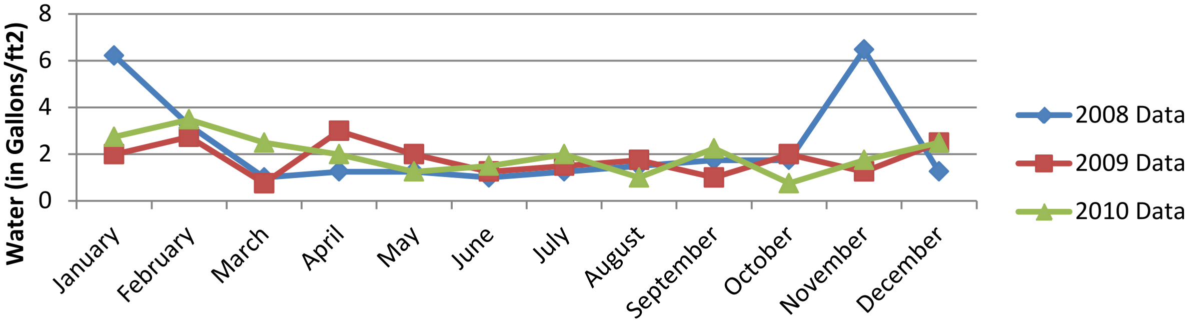

FIGURE 4.16
Water Use for Larned

4.2.6 Jetmore

The Jetmore subarea, District 6, Area 3, Complex 218, was audited as a representative of District 6. The facility, built in 1967, has an office area of 2,501 square feet and a storage area of

1,998 square feet. Two heated bays, two unheated bays, interior office space, a washbay, and exterior storage make up the subarea complex. Jetmore features single-pane windows, a natural gas furnace, a 40-gallon natural gas water heater, natural gas radiant heaters, and T8 and incandescent lamps installed throughout. Graphs illustrating utility usage for Jetmore can be found in Figure 4.17, 4.18, and 4.19. The Jetmore blower door test was inconclusive as a result of equipment problems.

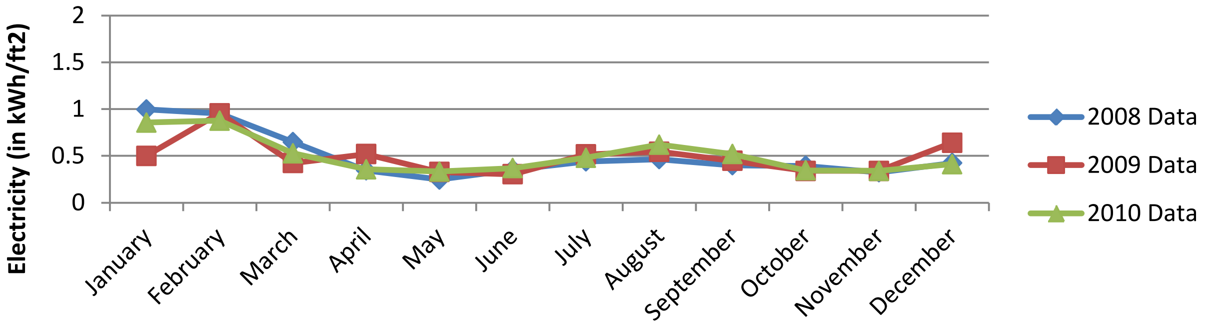

FIGURE 4.17
Electricity Use for Jetmore

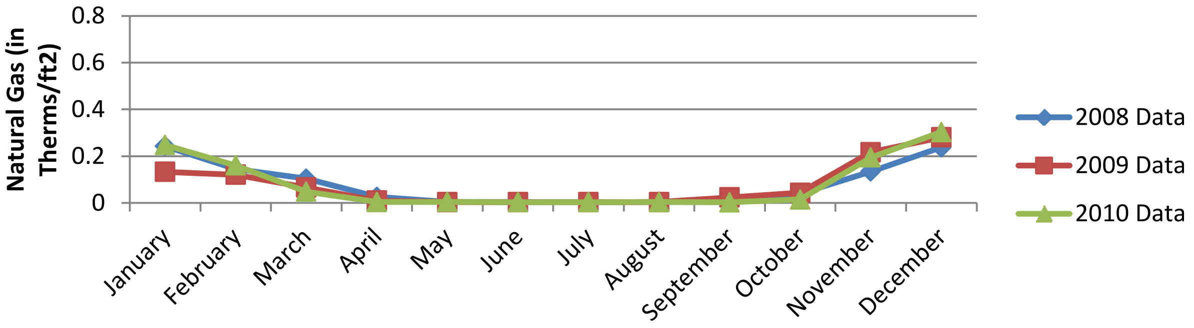

FIGURE 4.18
Natural Gas Use for Jetmore

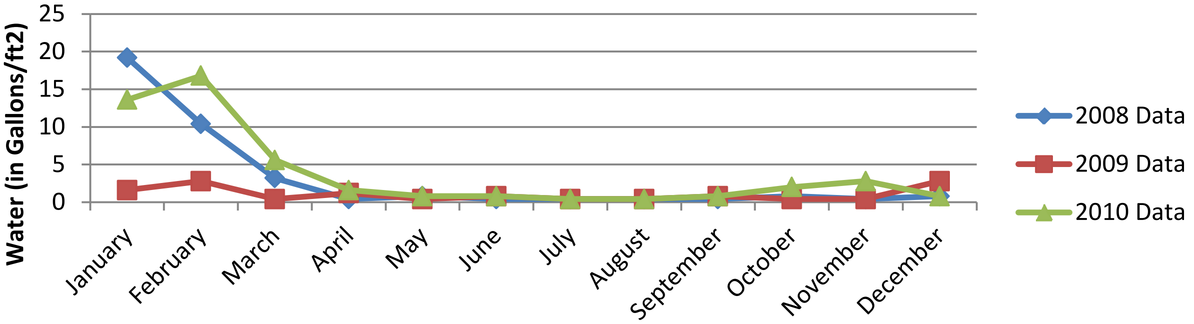

FIGURE 4.19
Water Use for Jetmore

As a summary of the data collected, see Table 4.1 below to compare building features and systems and Table 4.2 to compare the monthly average utility consumption between the six KDOT facilities. Further discussion on the audit results represented in the tables can be found in report sections 4.4 and 4.5. Also, Figures 4.20, 4.21 and 4.22 display the average utility usage from 2008 to 2010 for all six facilities all on one graph to aid in comparison.

TABLE 4.1
Summary of Facility Characteristics for All Six Selected KDOT Facilities

	Audited KDOT Facilities					
	Atchison	Belleville	Russell	Altamont	Larned	Jetmore
Office Area	4277 sf	4203 sf	4138 sf	2431 sf	4024 sf	2501 sf
Washbay/ Storage Area	2980 sf	3027 sf	2986 sf	1755 sf	3067 sf	1998 sf
Quantity of Heated and Unheated Bays	2 / 4	2 / 4	2 / 4	4 / 0	2 / 4	2 / 2
Window Panes	Single-pane	Double-pane	Double-pane	Double-pane	Double-pane	Single-pane
Heating	(2) NG Furnaces	NG Furnace	NG Furnace	Electric PTACs	NG Furnace	NG Furnace
Water Heater	30-Gallon Natural Gas	8-Gallon Electric	29-Gallon Natural Gas	6-Gallon Electric	40-Gallon Natural Gas	40-Gallon Natural Gas
Lamps	T12, Incand.	T8, Incand.	T5HO	T8	T12, T5, Incand.	T8, Incand.

* NG = Natural Gas, PTAC = Packaged Terminal Air Conditioners

TABLE 4.2
Monthly Average Utility Consumption (2008–2010) for All Six Selected KDOT Facilities

	Audited KDOT Facilities					
	Atchison	Belleville	Russell	Altamont	Larned	Jetmore
Electricity Average (kWh/sf)	0.8479	1.0196	0.5025	0.7370	0.6512	0.4964
Natural Gas Average (Therms/sf)	0.0762	0.1005	0.1063	0.1332	0.0852	0.0794
Water Average (Gallons/sf)	2.0026	3.2351	0.8619	1.8739	2.0295	2.6767

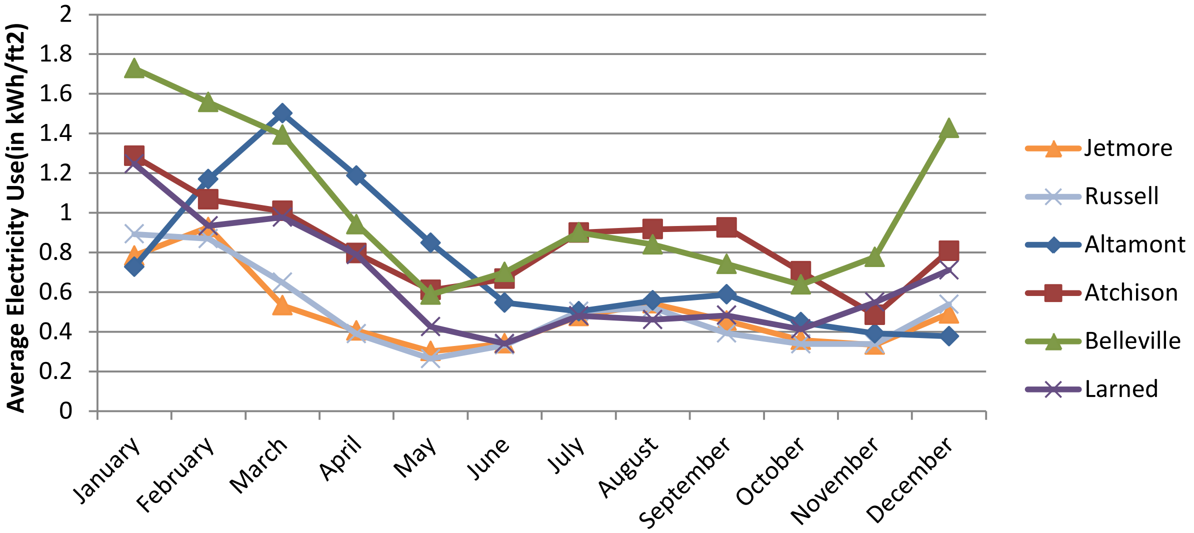

FIGURE 4.20
Electricity Use Comparison

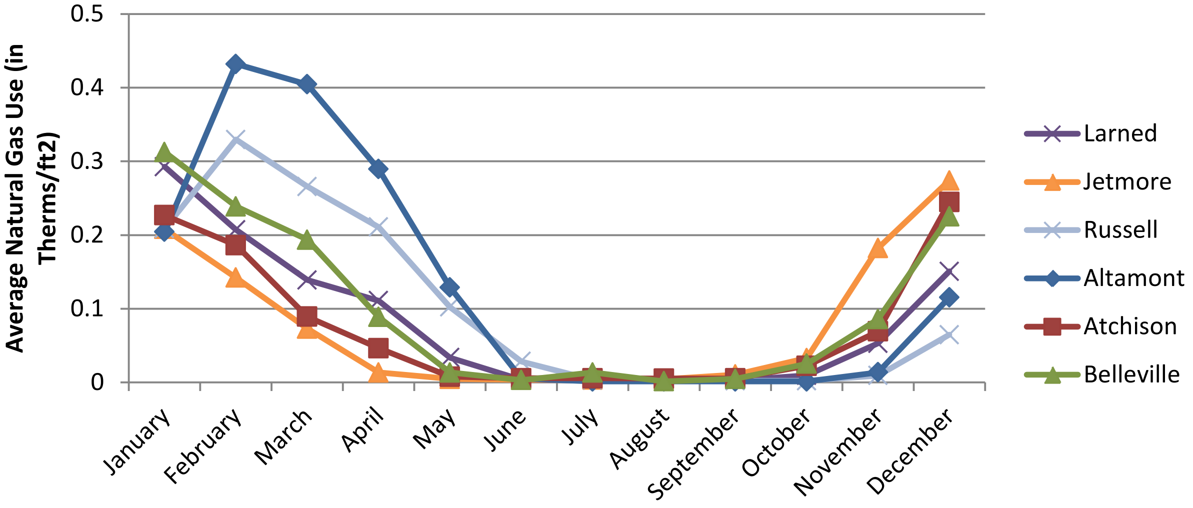

FIGURE 4.21
Natural Gas Use Comparison

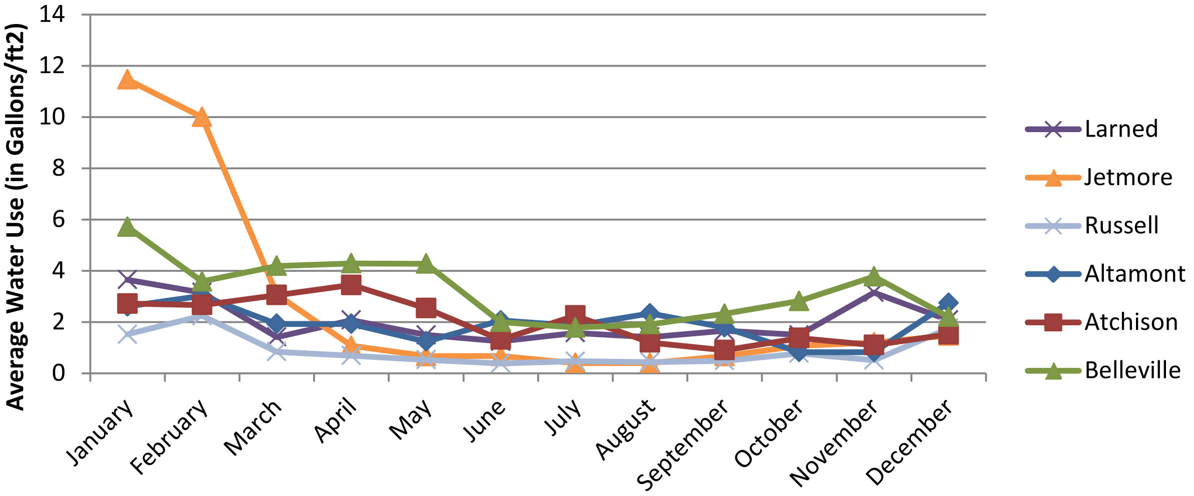

FIGURE 4.22
Water Use Comparison

4.3 Common Energy Consumption Issues

Each KDOT facility that was audited had specific issues hindering energy efficiency. Many of the facilities had similar issues that cause problems when trying to reduce energy consumption. These common issues included: envelope / windows, hot water heaters, lighting, and low-efficiency appliances.

First is the issue of a building envelope with specific attention to single-pane windows, or poorly installed windows, ill-fitting doors and envelope joints. A leaky envelope or poor windows cannot keep the outdoor conditions from entering the building. This can cause the mechanical heating and cooling system to work harder to overcome the additional heat or cold from the outdoors. To determine the severity of incoming air, the audit team conducted a blower door test which depressurizes the building space to negative 70 Pascals (0.01 psi), allowing for outside air to be drawn into the building through leaks in the building envelope. Infrared pictures, catalogued in Appendix C, were taken during the pressure test to indicate areas of infiltrating air because of the colder temperatures during the audit, the infiltrating air was colder than the inside air and can be seen as purple or blue in the thermal images. The pictures confirmed ill-fitting windows and doors, along with poorly sealed wall and ceiling joints. Infiltration has a negative impact on the building's mechanical system, making it work harder to maintain temperatures within the space and makes it nearly impossible to control building moisture levels.

Next, oversized water heaters were a common problem throughout the facilities. The buildings had large water heaters when their demand was only to provide hot water to two or three sinks. By having an oversized water heater, excess water is heated and stored which results in stand-by loss of energy.

The third common occurrence was the use of energy-draining light bulbs. One-third of the facilities use T12 fluorescents and two-thirds of the facilities have incandescents, which draw a lot of power for a relatively low light output and are considered outdated technology. For example, a T12 can only produce 70 lumens of light per Watt of energy, while today's more industry accepted lamp, T5 fluorescent, can produce 100 lumens per Watt. The Atchison and Russell facilities have similar light levels, at 6 - 42.5fc and 8.6 - 65 fc, respectively; however, the lamps utilized within the buildings are T12s and incandescents in Atchison and T5s in Russell. An examination of electricity use in September, a moderate month that most likely requires little heating or cooling needs, the electricity usage between facilities easily depicts the excess energy required by T12s to provide the same lumen quantity as T5s. In September of 2010, Atchison used 1.0414 kWh/SF of electricity while Russell used 0.3335 kWh/SF.

Currently installed appliances are either not Energy Star certified, or are very low on the Energy Star rating scale. Energy Star ratings are provided on labels affixed to equipment and appliances. Throughout the facility audits, any Energy Star labels present were examined. These appliances included the furnaces, water heaters, refrigerators, computers, printers, etc. The ratings often fell below the median certification value.

4.4 Individual Building Summaries

The individual building summaries that follow present the particular concerns for each facility that increase energy consumption and reduce overall building efficiency. The complete audits for each facility, as well as digital and thermal photos, can be found in Appendix C. Following the descriptions of each individual facility, Table 4.4, Facility Summary – Measured and Recommended Values, displays the actual measured values for interior lighting levels, water discharge temperature, and room temperature settings. The table displays the individual facility measured values, plus the standard values recommended by the IESNA Handbook, ASHRAE Standard 90.1-2010 and the Department of Energy. The measured values can also be found in Appendix C with the complete facility audits. The following subsections are intended to document the issues or specific areas that excelled for each facility. Further discussion of how to address these issues are given in section 4.5.

4.4.1 Atchison

The District 1, Atchison subarea had many energy inefficient components. First, the facility has single-pane windows that are drafty and ill-fitted to the building openings. Figures 4.23 through 4.32 depict problem areas within the building that allow outside air to infiltrate indoors.

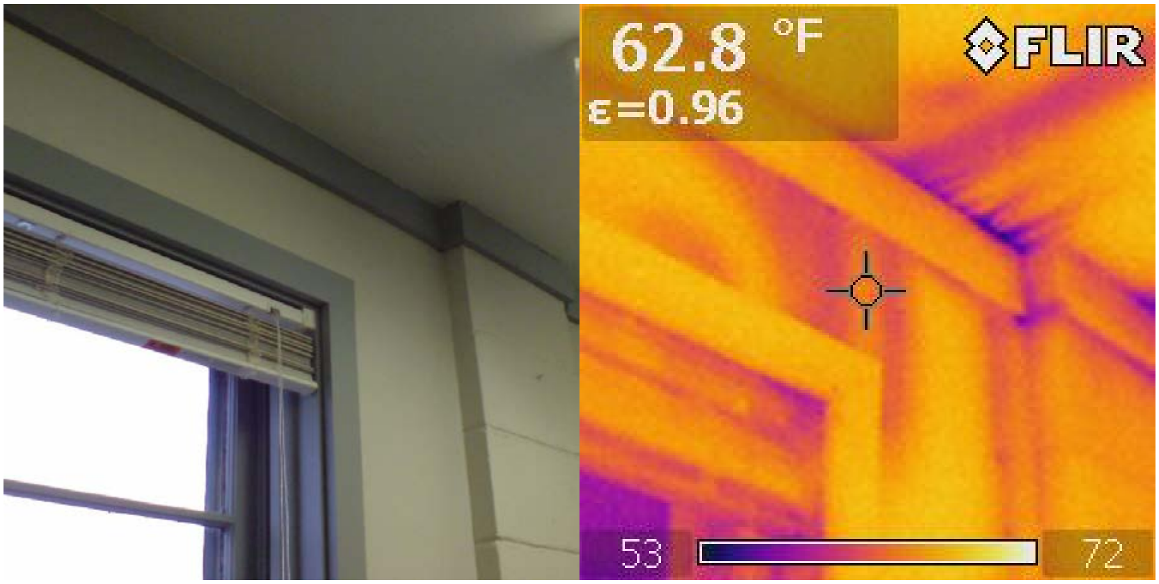

FIGURE 4.23
Infiltration Detection—Wall and Ceiling Seam

FIGURE 4.24
Infiltration Detection—Ceiling Penetration

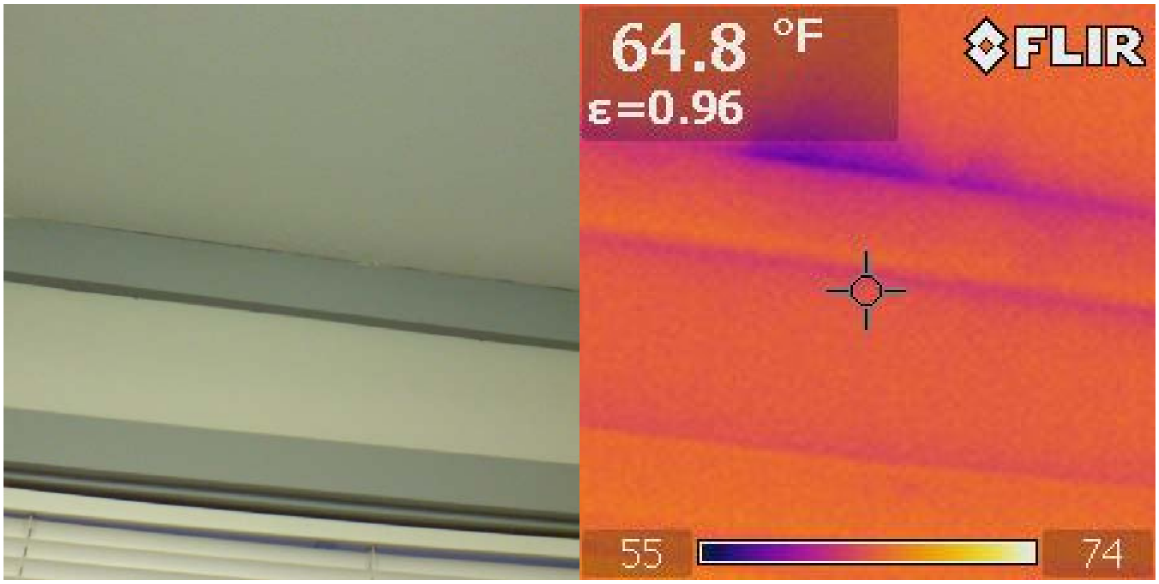

FIGURE 4.25
Infiltration Detection—Wall and Ceiling Seam

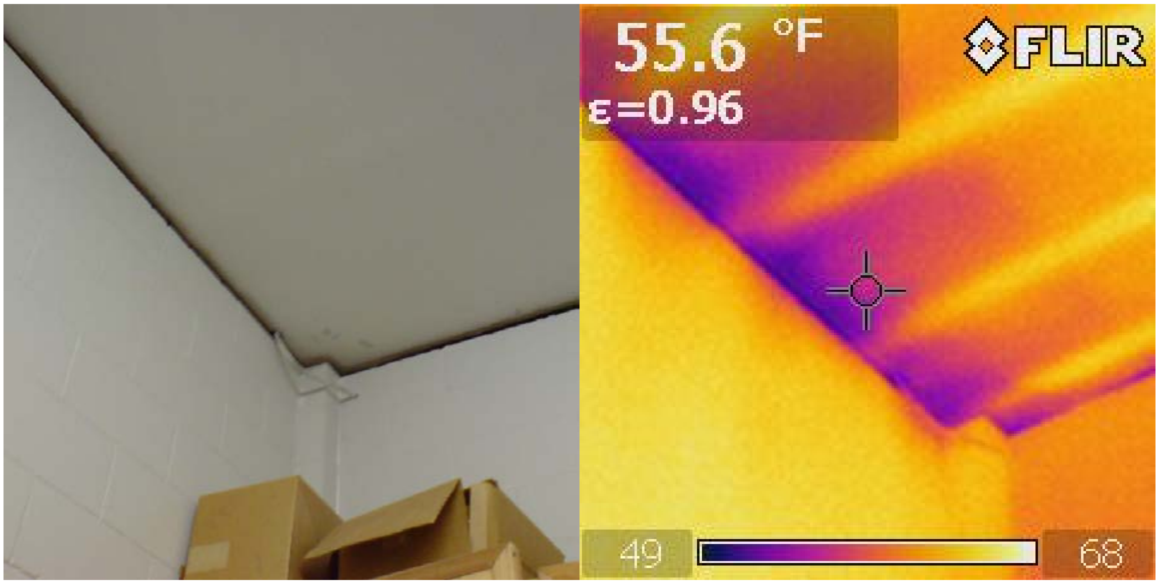

FIGURE 4.26
Infiltration Detection—Wall and Ceiling Seam

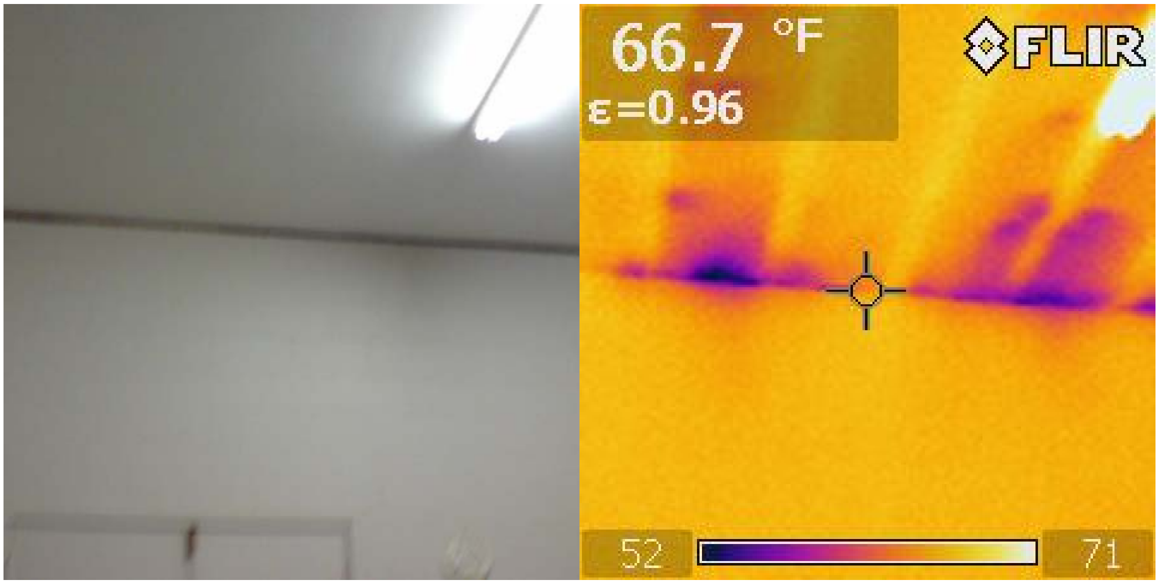

FIGURE 4.27
Infiltration Detection—Wall and Ceiling Seam

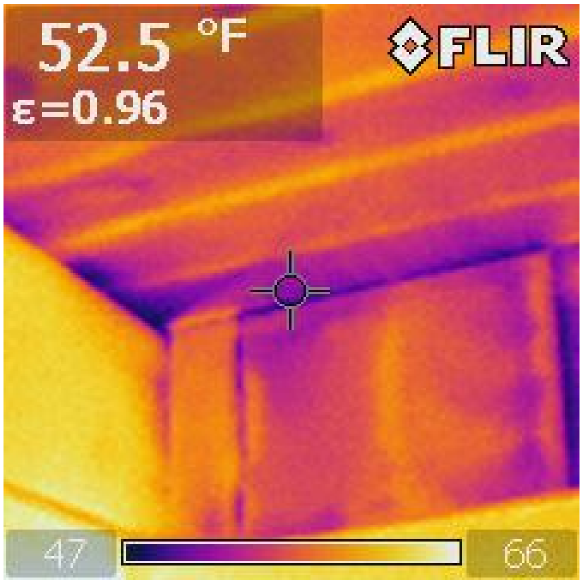

FIGURE 4.28
Infiltration Detection—Supply Air Diffuser

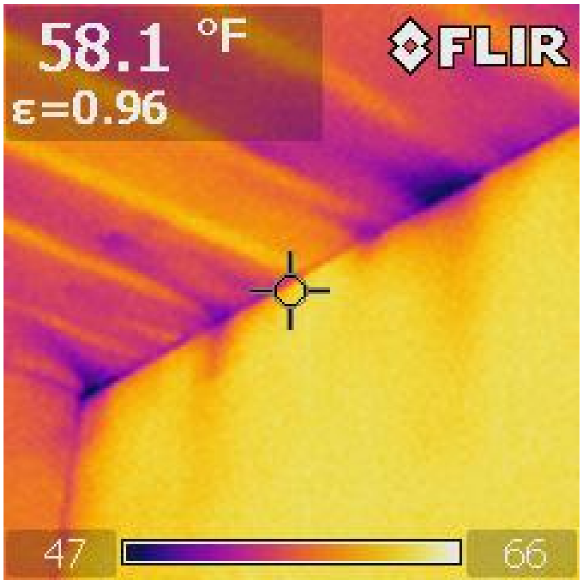

FIGURE 4.29
Infiltration Detection—Wall and Ceiling Seam

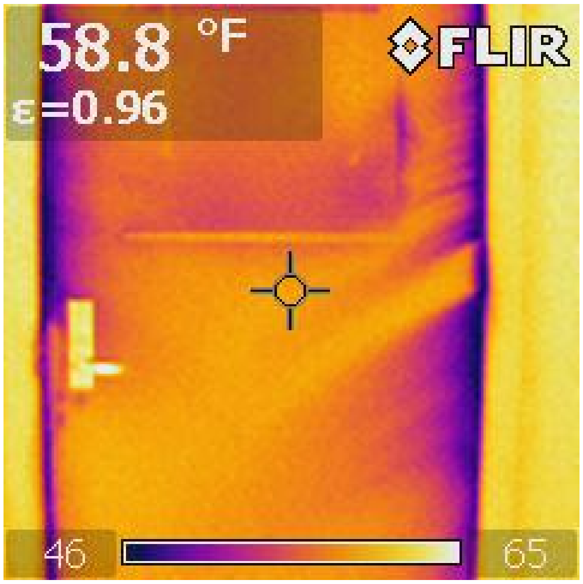

FIGURE 4.30
Infiltration Detection—Exterior Door

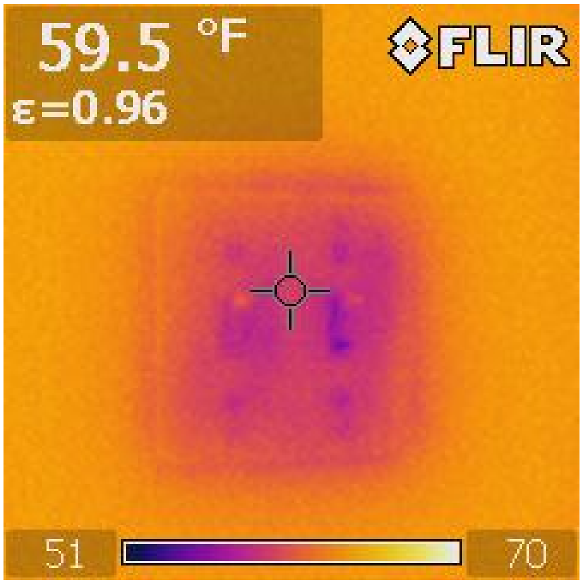

FIGURE 4.31
Infiltration Detection—Light Switch

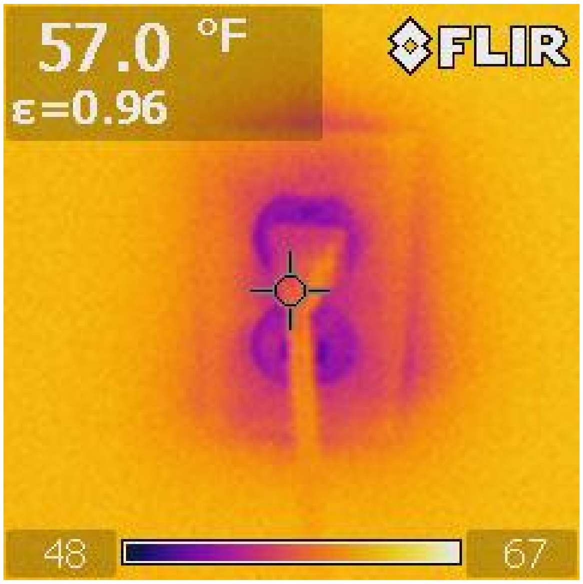

FIGURE 4.32
Infiltration Detection—Wall Outlet

The facility also has an oversized 30-gallon water heater that has a higher than necessary discharge temperature of 117 degrees Fahrenheit. The maximum discharge temperature from a lavatory in a public facility, according to ASHRAE Standard 90.1-2010, is 110°F and the storage temperature of the water should not exceed the intended use temperature. Inefficient T12 and incandescent lamps are used in lighting fixtures throughout the facility, providing audit readings of 6.0-42.5 footcandles throughout the interior spaces. A footcandle is a unit to describe the amount of illuminance measured in a one foot radius circle around any point. The footcandle values are within the recommended level of 30-50 footcandles; however, the interior lighting power density (LPD) calculated in Tables E.15 and E.16 is 1.32 W/SF. The calculation for Atchison can also be seen in Table 4.3.

TABLE 4.3
Atchison Light Power Density Calculation

Location:	**Atchison**			
Office SF:	4551	SF		
Lamp Type	Quantity	Wattage	Total W	
T12, 34W	124	34	4216	
Incan, 60W	30	60	1800	
			1.3219073	W/SF

The LPD was the highest out of all six facilities and correlated with the greatest lighting-dedicated energy consumption among the six facilities with 0.564 kWh/SF. Controls for the furnace are simple, with a single temperature set point thermostat and an on-off switch. Lastly, appliances are either low Energy Star certified or not certified at all.

4.4.2 Belleville

Belleville subarea in District 2 also has energy efficiency flaws. Similar to the Atchison subarea, exterior penetrations and joints in the facility are drafty, resulting in infiltration seen in Figures 4.33 through 4.42.

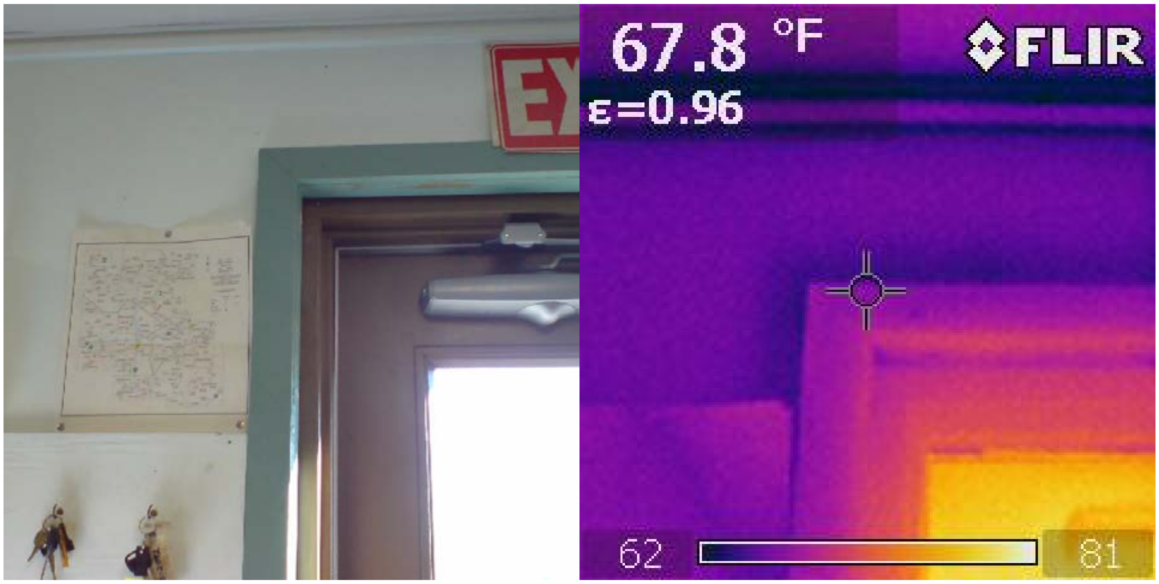

FIGURE 4.33
Infiltration Detection—Exterior Door

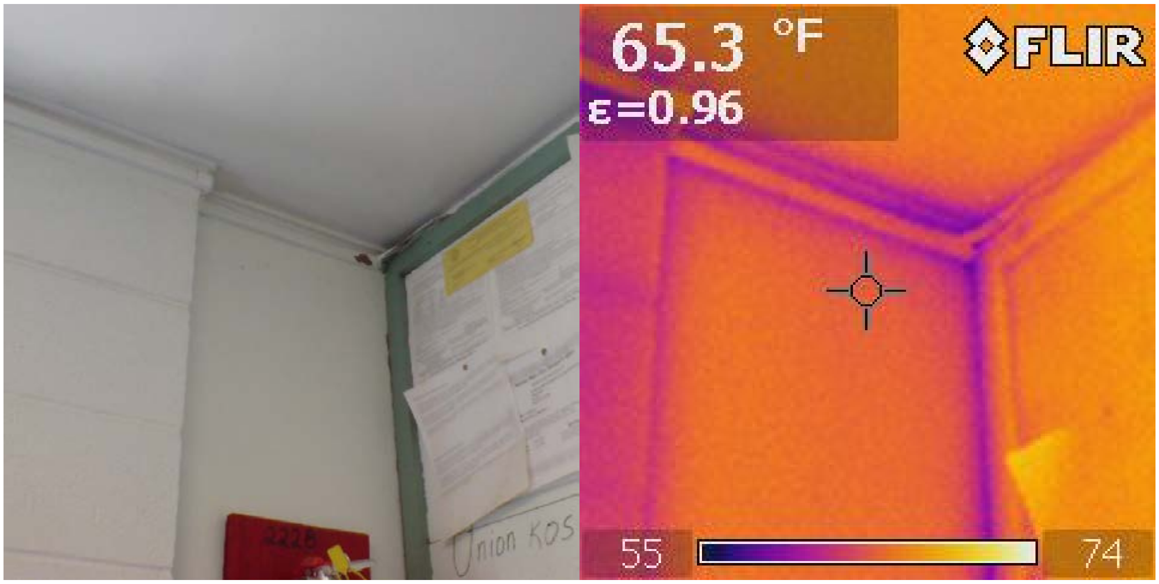

FIGURE 4.34
Infiltration Detection—Wall and Ceiling Seams

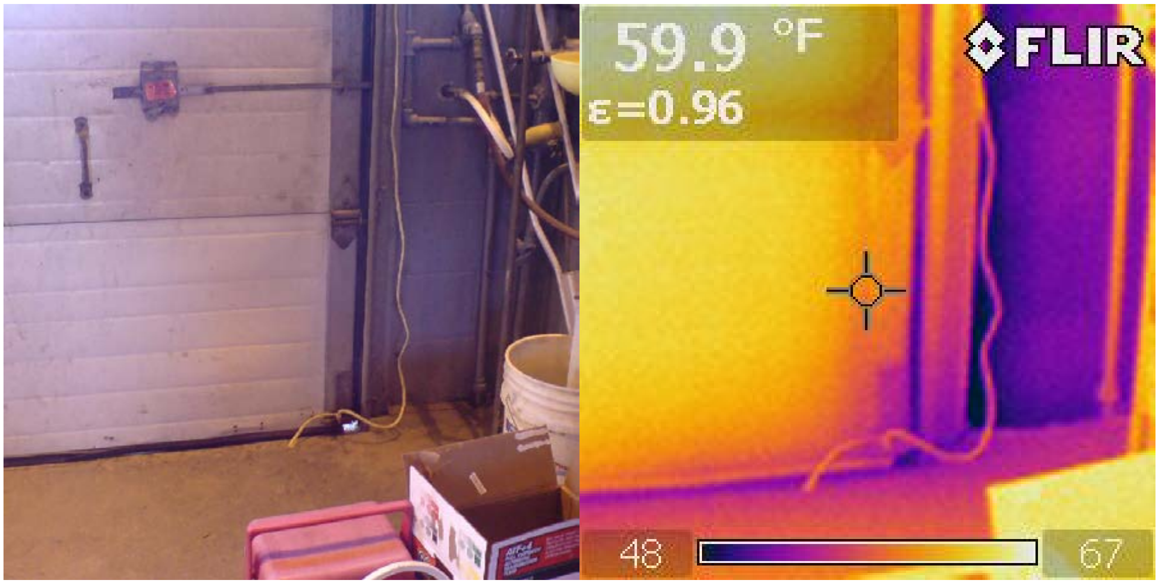

FIGURE 4.35
Infiltration Detection—Bay Door

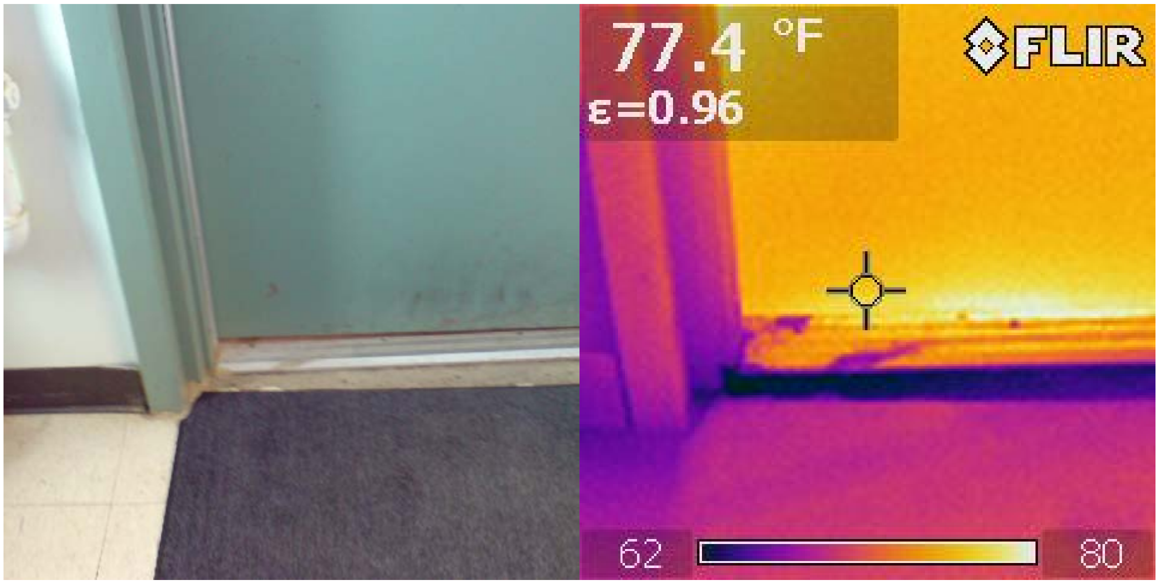

FIGURE 4.36
Infiltration Detection—Exterior Door

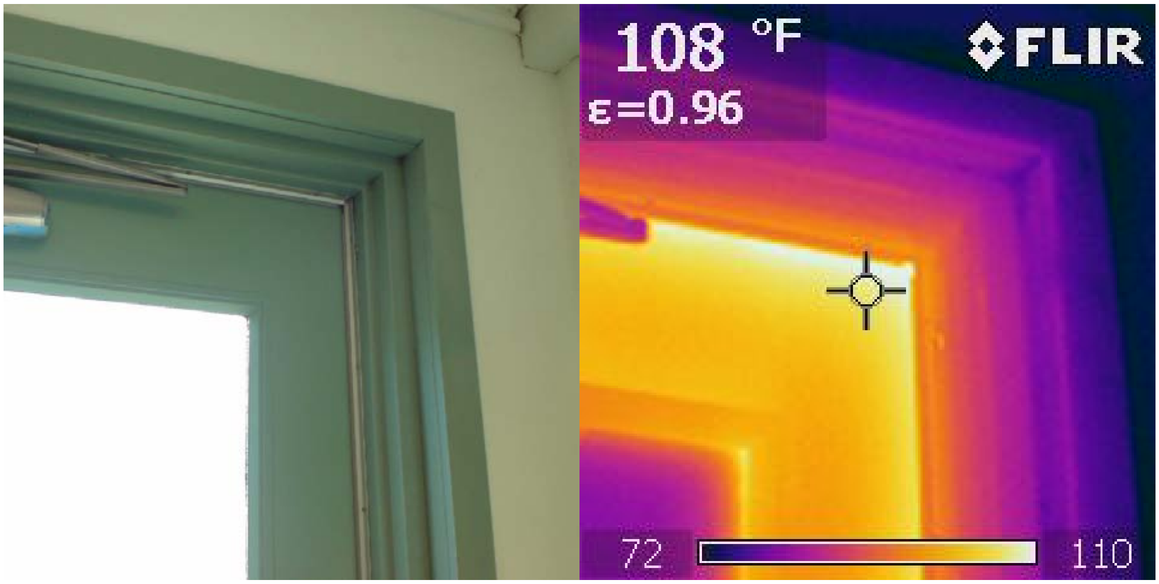

FIGURE 4.37
Infiltration Detection—Exterior Door

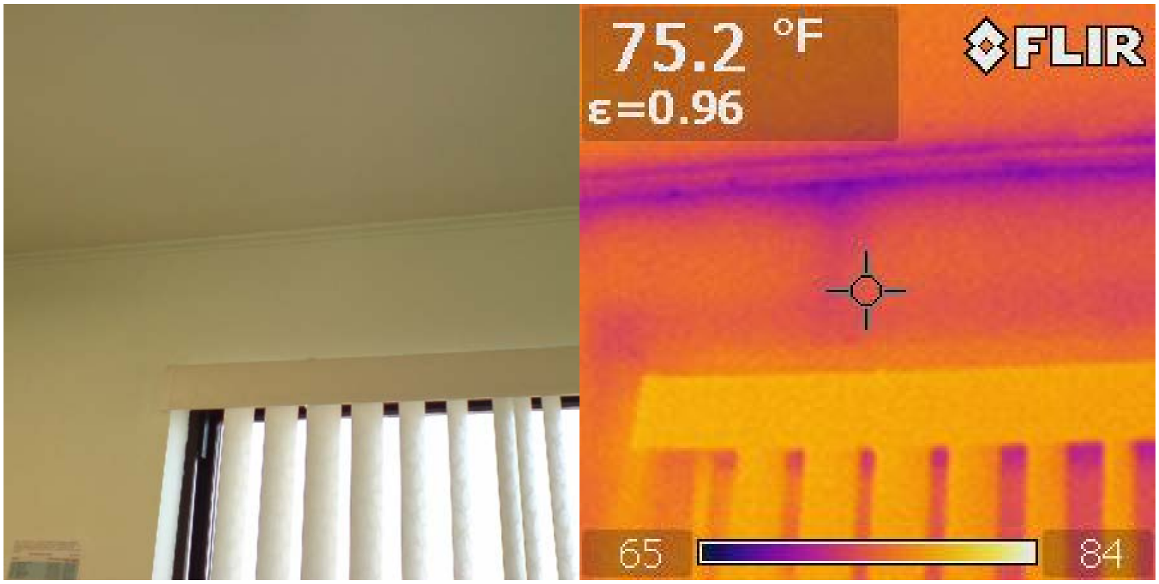

FIGURE 4.38
Infiltration Detection—Wall and Ceiling Seam

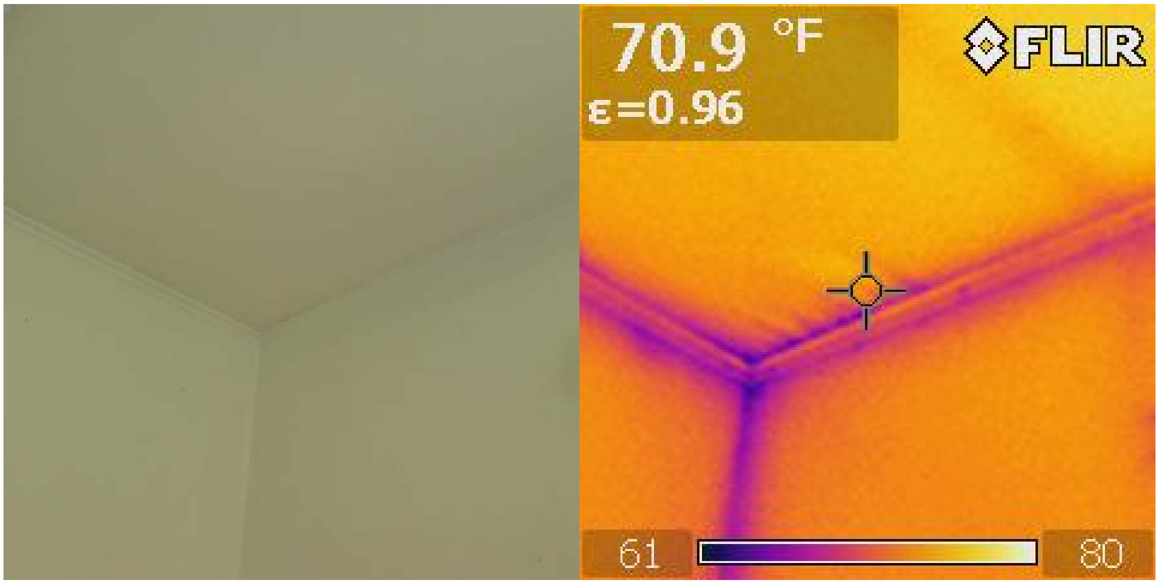

FIGURE 4.39
Infiltration Detection—Wall and Ceiling Seams

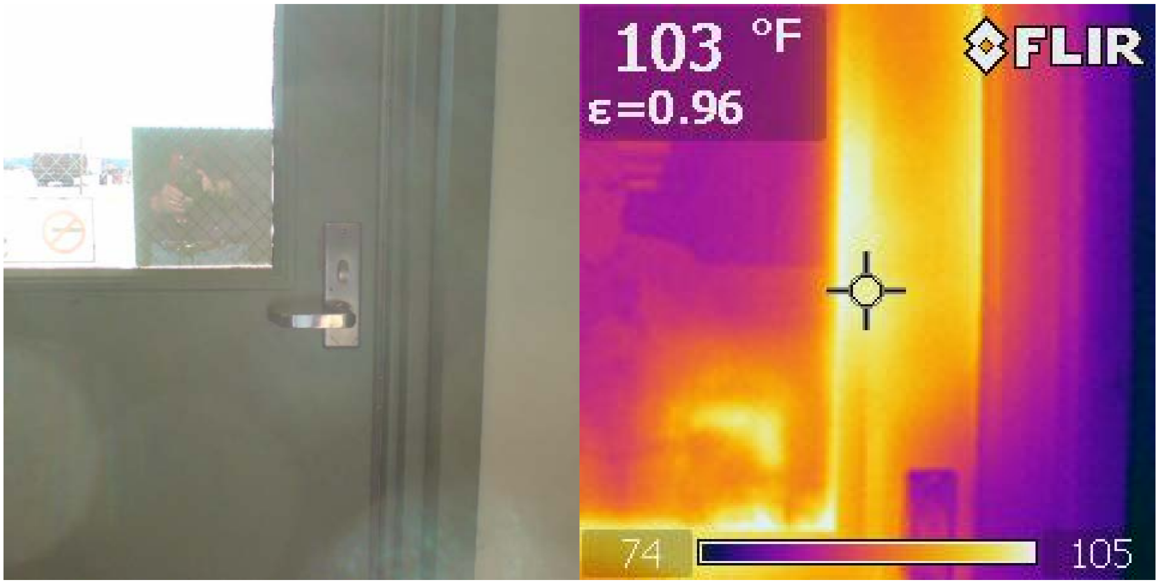

FIGURE 4.40
Infiltration Detection—Exterior Door

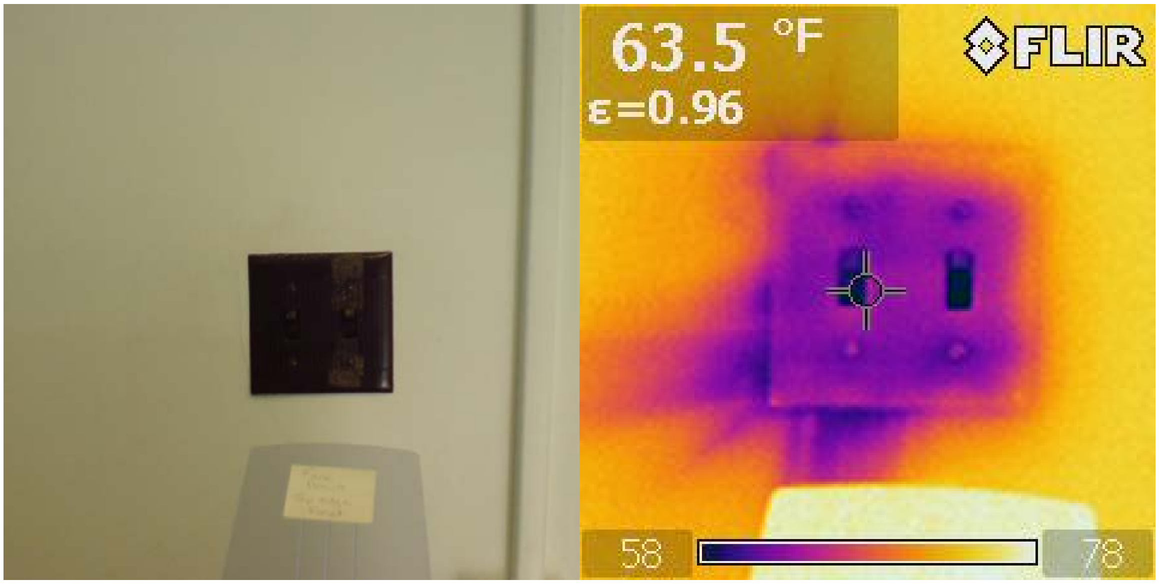

FIGURE 4.41
Infiltration Detection—Light Switch

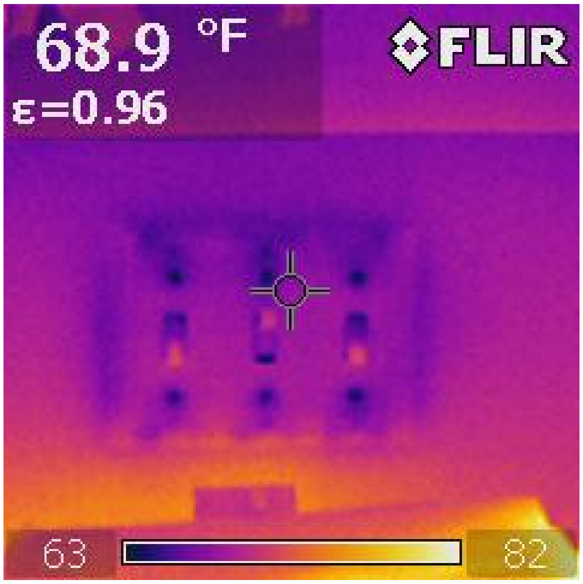

FIGURE 4.42
Infiltration Detection—Light Switch

While the water heater at Belleville is appropriately sized, the discharge temperature is too high at 141 degrees Fahrenheit. Lighting levels in the offices are very high at this facility ranging from 85-111 footcandles. The high lighting level correlates to the second highest LPD, calculated in Table E.15 and E.16, for the office space of 1.245 W/SF. Belleville had the second highest LPD, relating to the second highest energy consumer with 0.555 kWh/SF. Lastly, appliances are low efficiency and some are not Energy Star certified.

4.4.3 Russell

The audit of the District 3 facility, Russell, provided knowledge of the inefficient components of the subarea. Comparable to other facilities, the water heater was a 29-gallon oversized natural gas heater; however the water discharge temperature was appropriate at 104 degrees Fahrenheit. The controls for the furnace were rudimentary and do not allow for programming. The lamps utilized in the Russell facility were T5s, the most energy-efficient linear fluorescent option available. To confirm the energy efficiency of the lamps used, the LPD calculated in Appendix E, Tables E.15 and E.16 at Russell was only 0.421 W/SF and had the lowest energy consumption with 0.231 kWh/SF. As discussed in section 4.3, the Russell facility used nearly three times less energy than the Atchison facility in September 2010, supporting the claim that T5 lamps are much more energy efficient than T12s when comparing similar light levels. The appliances however were inefficient and lacked high Energy Star certifications. Lastly, the building was poorly sealed and allowed for infiltration. Figures 4.43 through 4.48 depict various leaking points in the building’s envelope.

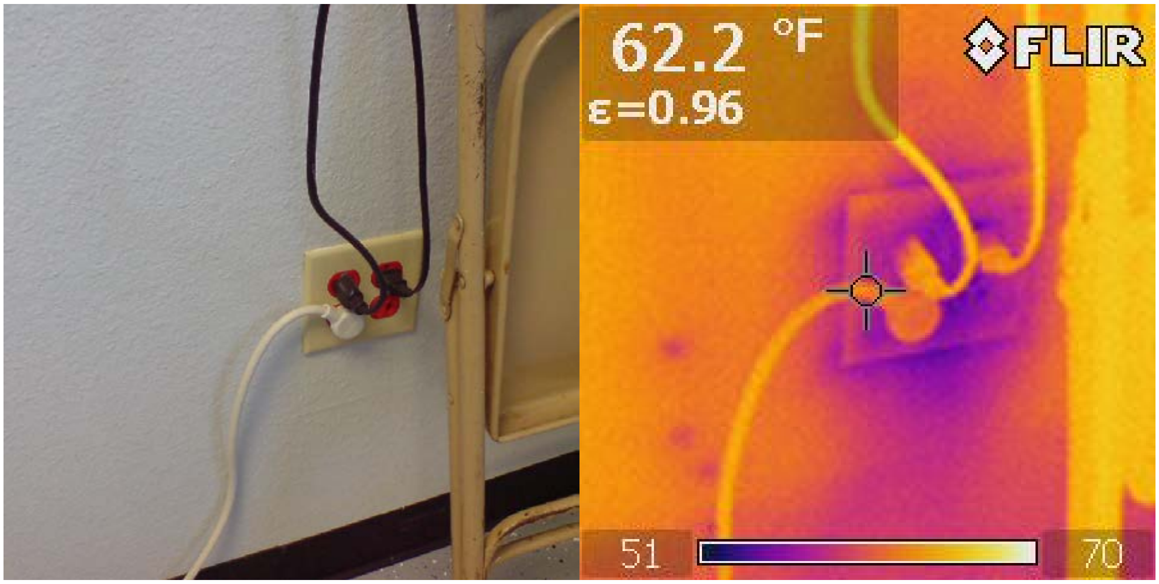

FIGURE 4.43
Infiltration Detection—Electrical Outlet

FIGURE 4.44
Infiltration Detection—Windows

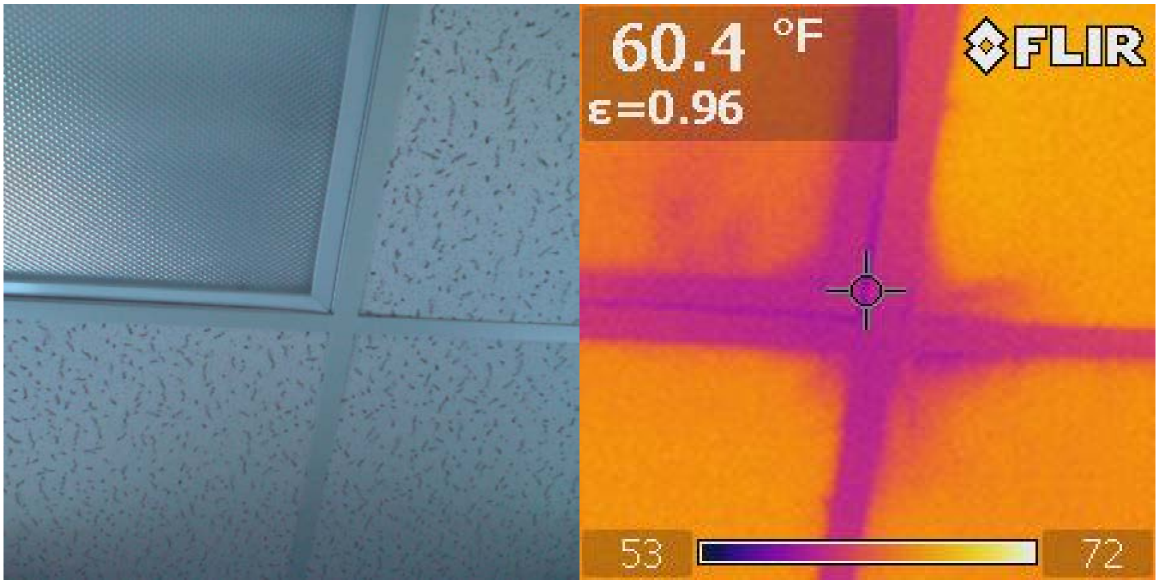

FIGURE 4.45
Infiltration Detection—Ceiling Grid Seams

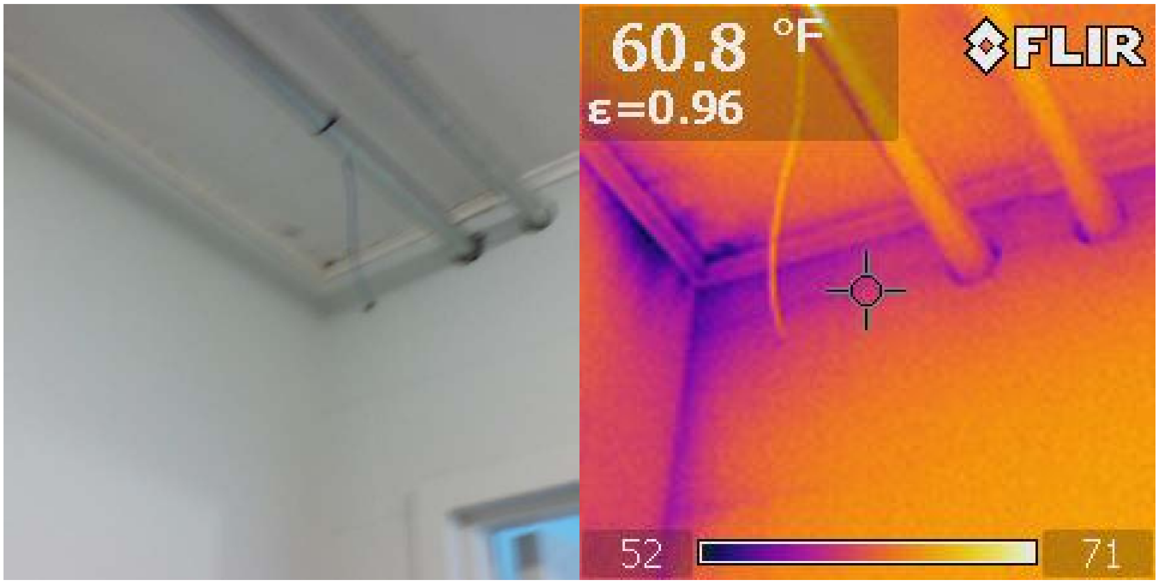

FIGURE 4.46
Infiltration Detection—Wall Penetrations and Seams

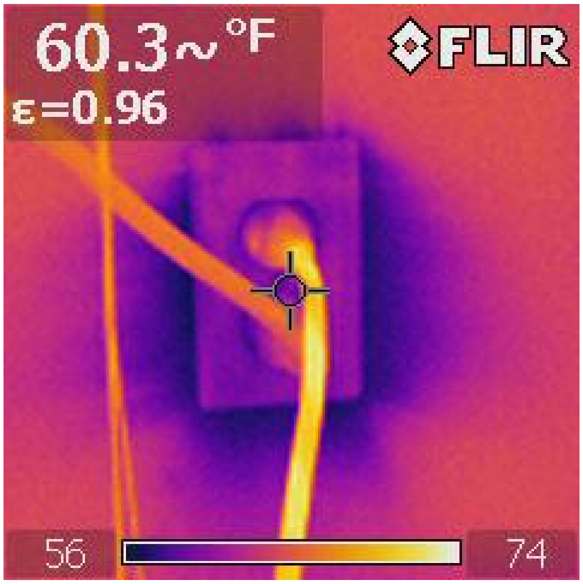

FIGURE 4.47
Infiltration Detection—Electrical Outlet

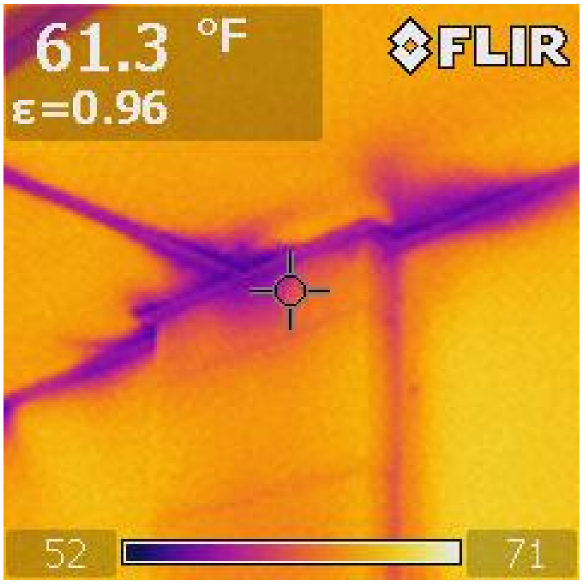

FIGURE 4.48
Infiltration Detection—Wall and Ceiling Seams

4.4.4 Altamont

The District 4 facility of Altamont was subject to issues prevalent in previous facilities and districts. First, the lighting fixtures and lamps provided more than adequate light levels of 42-130 footcandles. The lamps utilized are T8s are efficient; however, the high light levels negate the energy savings. While the water heater is appropriately sized at six-gallons, the discharge temperature is higher than necessary at 114 degrees Fahrenheit. Since Altamont has an electric water heater, the energy consumption cannot be easily compared to the facilities with natural gas water heaters because Altamont will draw energy for lighting and water heating throughout the year without any considerable peaks. Furthermore, infiltration is high in the facility due to exterior penetrations and building joints being inadequately sealed, as can be seen in Figures 4.49 through 4.53. The appliances are deficient, with little or no Energy Star ratings.

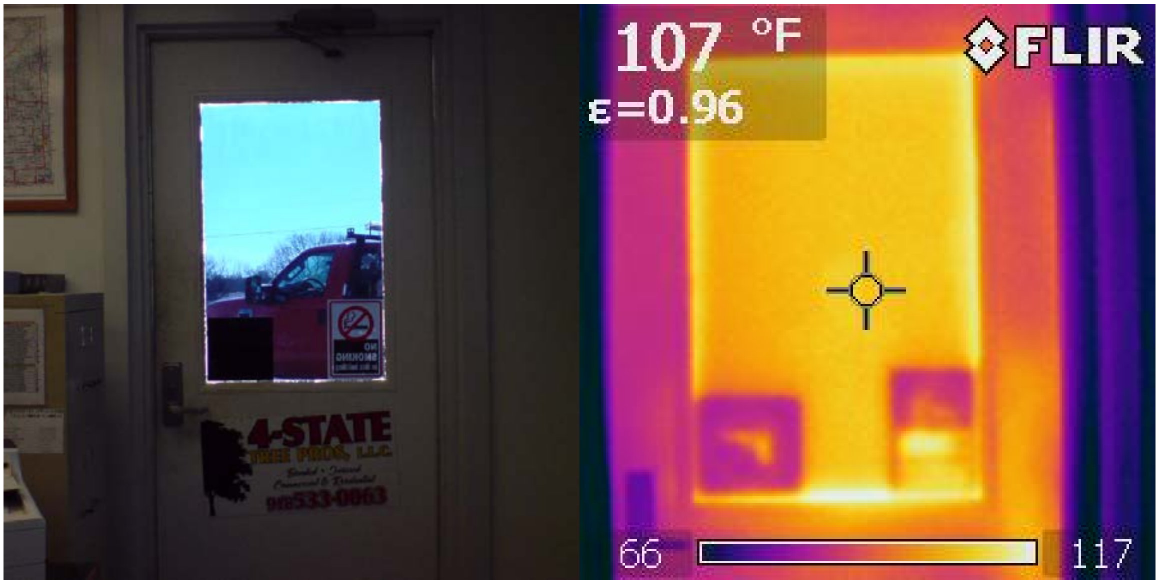

FIGURE 4.49
Infiltration Detection—Exterior Door

FIGURE 4.50
Infiltration Detection—Exterior Door

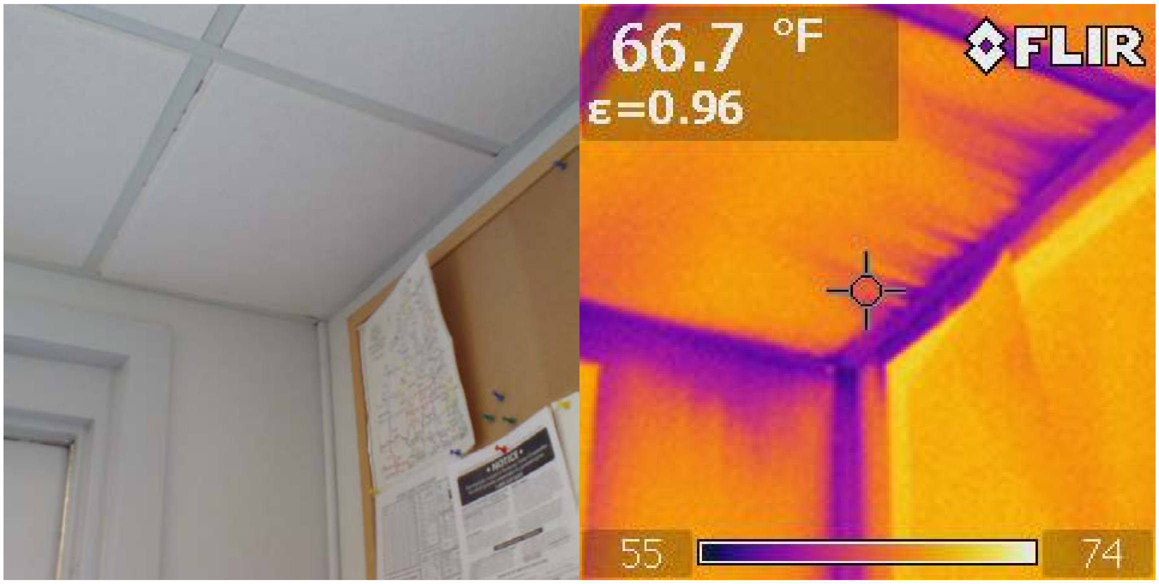

FIGURE 4.51
Infiltration Detection—Wall and Ceiling Grid Seams

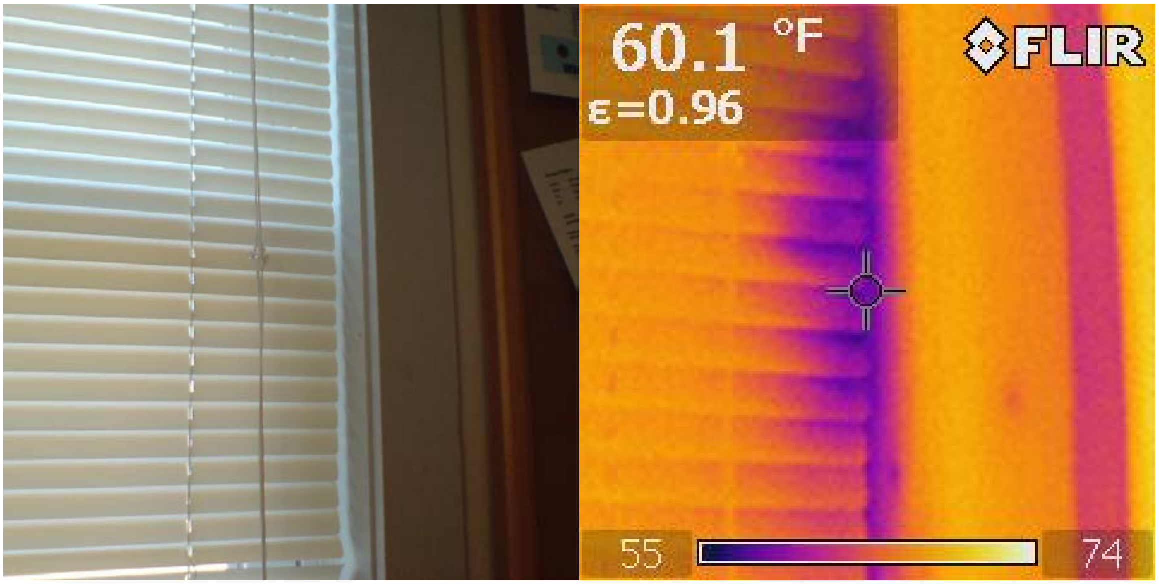

FIGURE 4.52
Infiltration Detection—Window

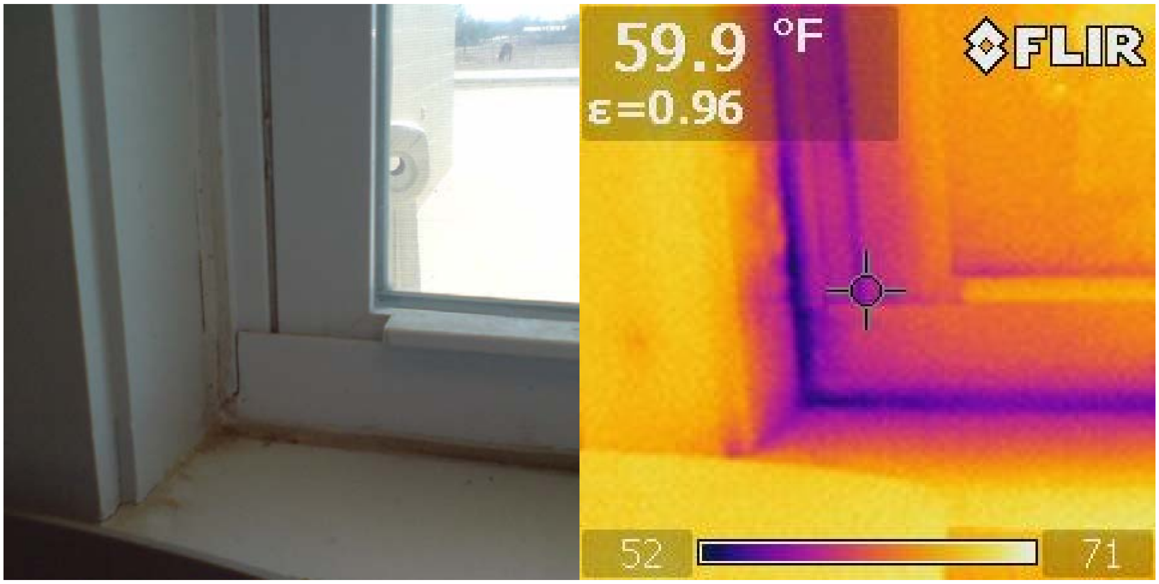

FIGURE 4.53
Infiltration Detection—Window

4.4.5 Larned

Larned, the subarea from District 5 studied, exhibited energy efficiency issues that were prevailing in prior audits. Once again, the water heater was oversized at 40-gallons. The HVAC controls were basic, with no programming available. In addition, the light fixtures utilize T12 and incandescent lamps, although high-efficiency T5 lamps are also used. Using both inefficient and highly-efficient lamps placed Larned in the middle of LPD and energy consumption values. The LPD at the facility was 0.612 W/SF and the energy consumption was 0.334 kWh/SF. Exterior penetrations and joints leak and allow for infiltration into the facility. Figures 4.54 through 4.59 illustrate areas of poor construction and lack of sealant around penetrations, leading to infiltration. Also, appliances lack high Energy Star ratings and are inefficient.

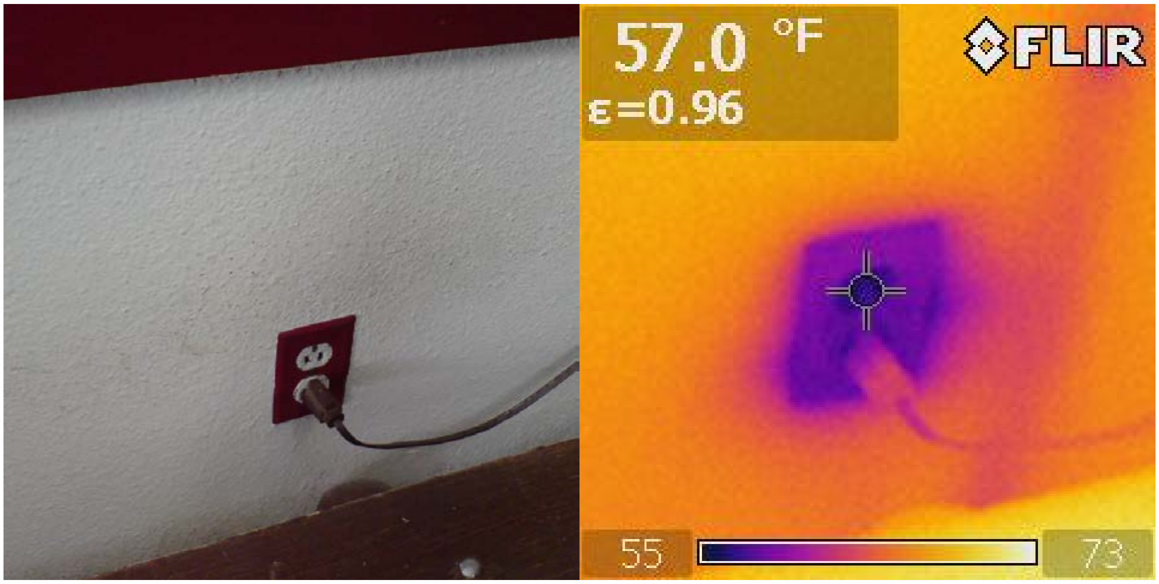

FIGURE 4.54
Infiltration Detection—Electrical Outlet

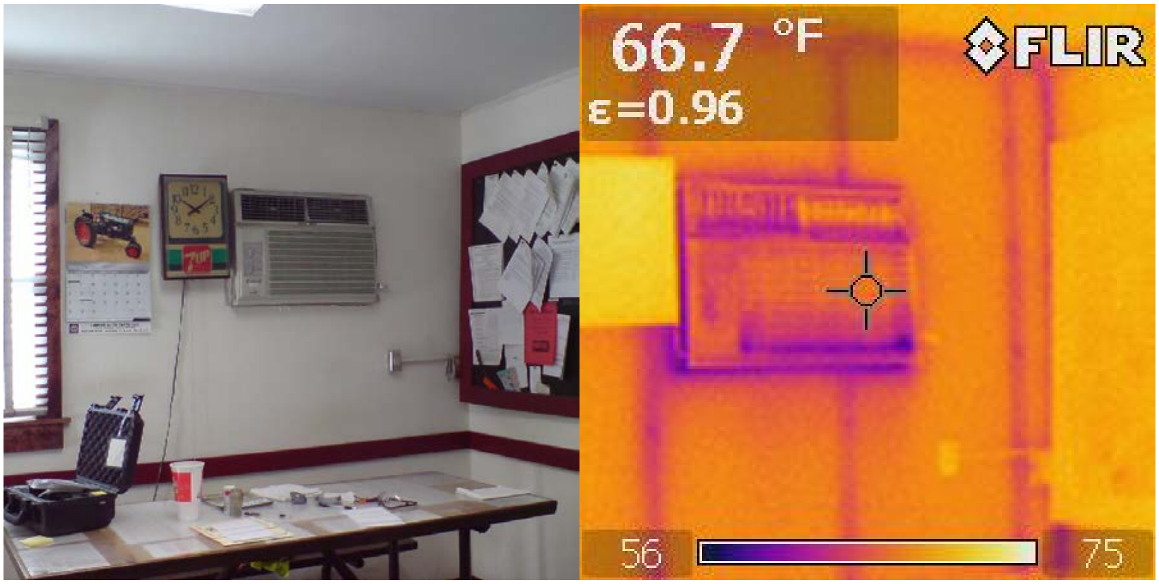

FIGURE 4.55
Infiltration Detection—Wall Penetration and Construction

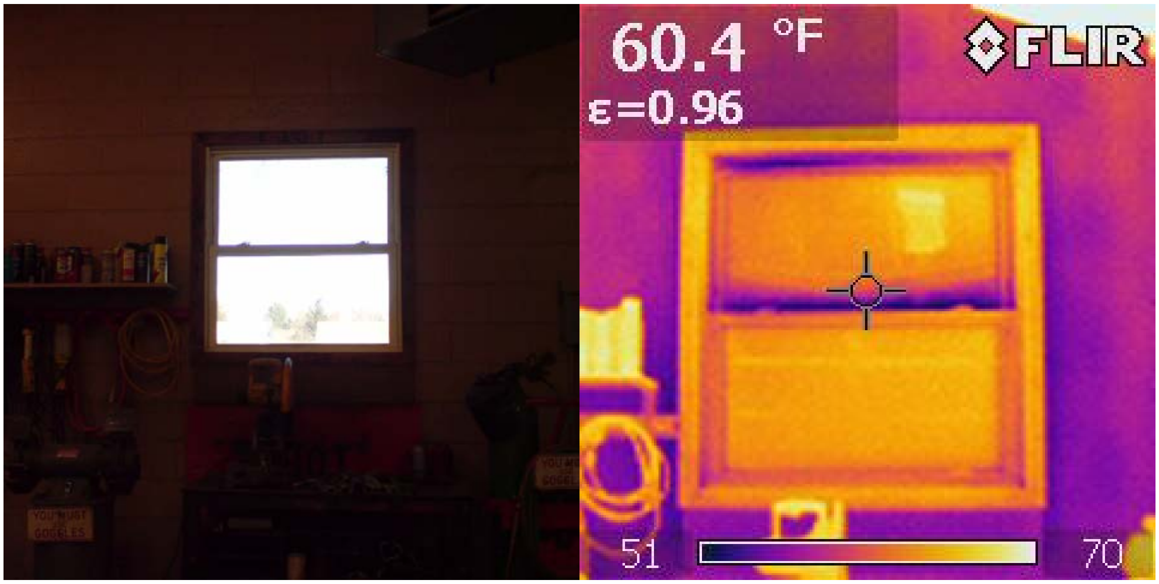

FIGURE 4.56
Infiltration Detection—Bay Window

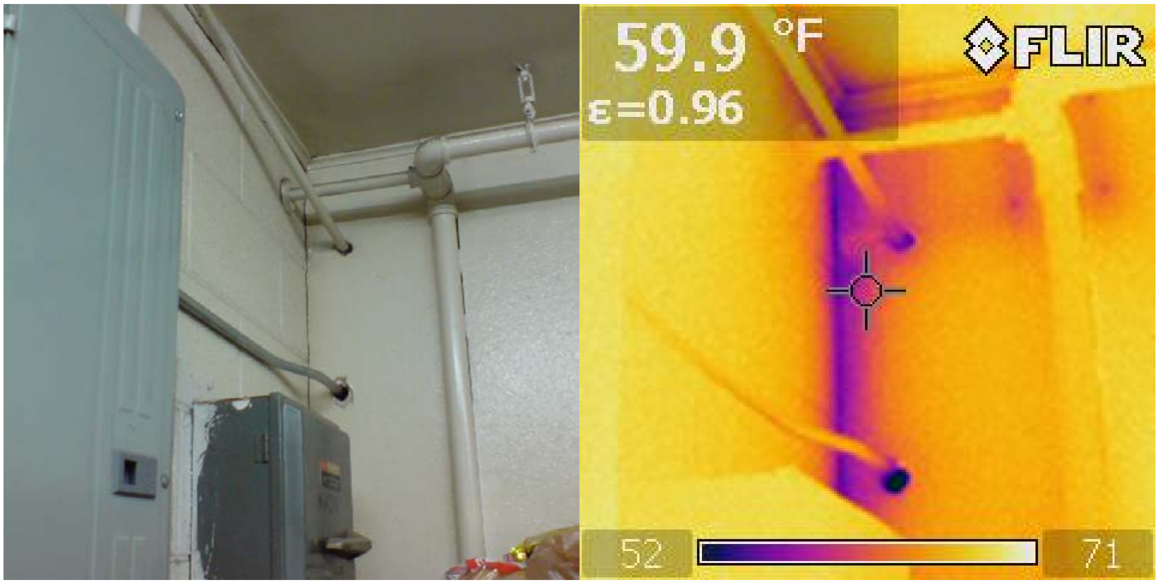

FIGURE 4.57
Infiltration Detection—Wall Penetrations and Seams

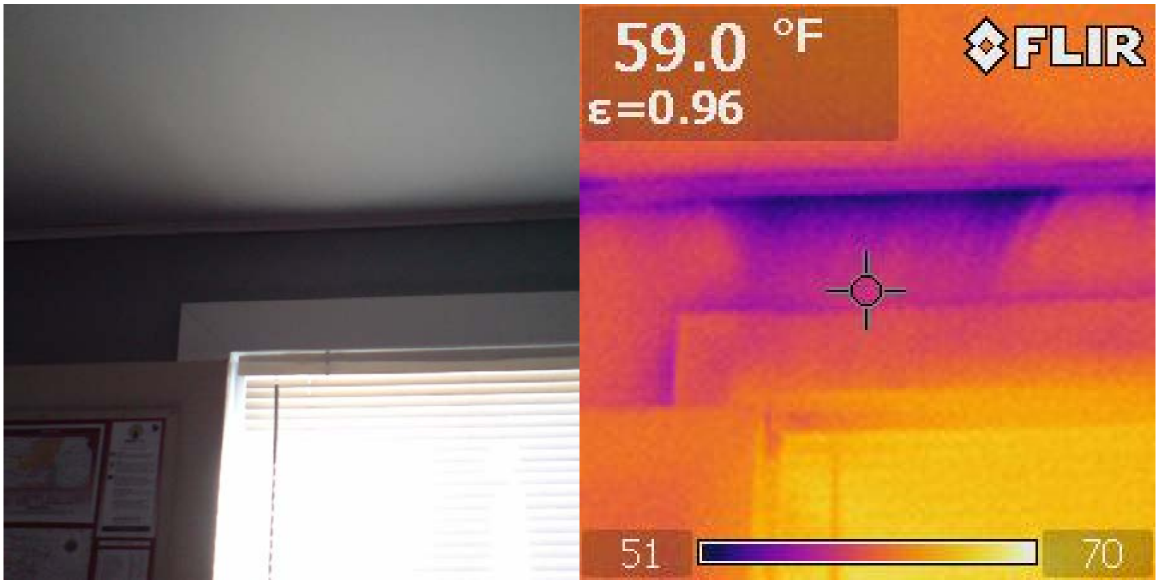

FIGURE 4.58
Infiltration Detection—Wall and Ceiling Seams

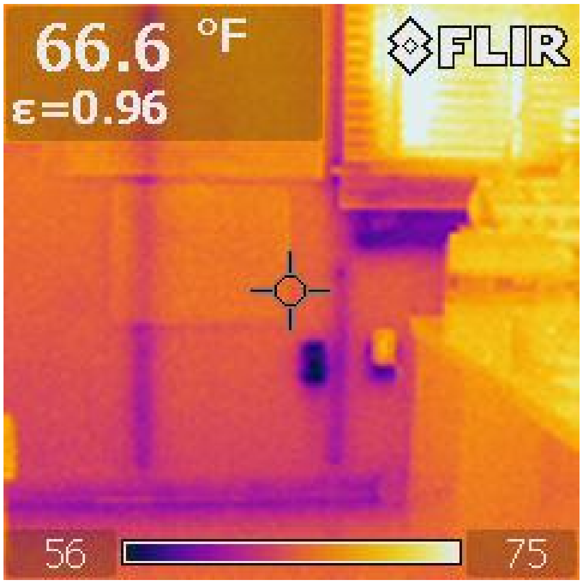

FIGURE 4.59
Infiltration Detection—Wall Construction

4.4.6 Jetmore

The District 6 facility of Jetmore exemplifies similar inefficiencies. First, the windows are single-pane and allow for heat gain and loss. As seen in Figures 4.60 through 4.63, the facility also has high infiltration as a result of poorly sealed penetrations and joints. The water heater is oversized at 40-gallons and the discharge temperature is too high at 117 degrees Fahrenheit. Also, the HVAC controls are nonprogrammable and need to be updated. Light fixtures and lamps are primarily incandescent and inefficient, although efficient T8s are also used. Much like Larned, the Jetmore facility combined inefficient and efficient lamps, allowing for a middle position in energy consumption. The LPD for Jetmore was 0.705 W/SF and the electric energy consumption was 0.277 kWh/SF. Moreover, the appliances are not Energy Star rated and are inefficient.

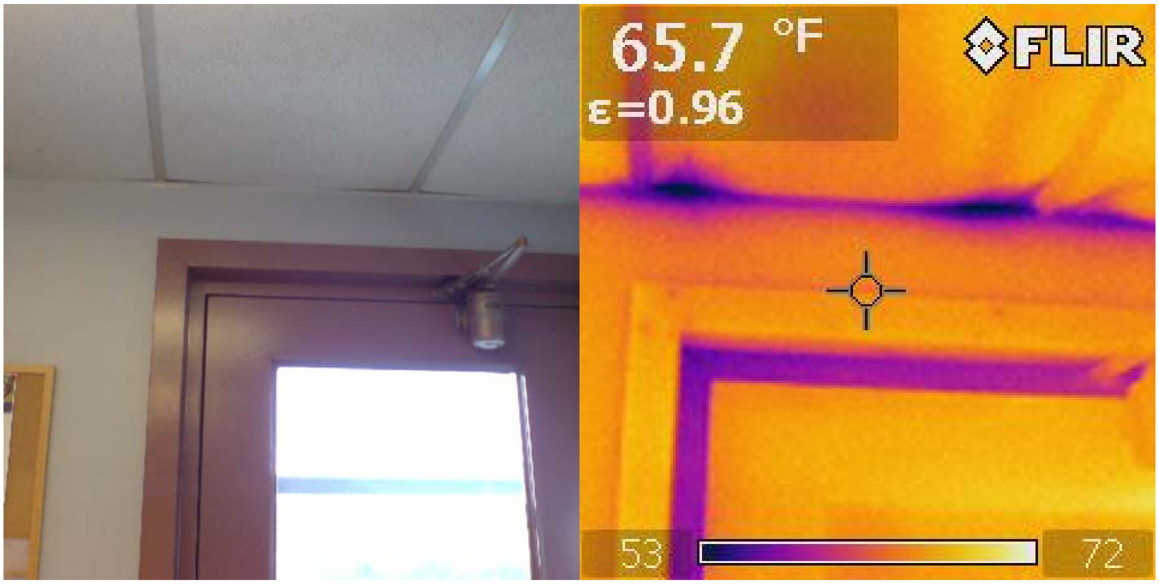

FIGURE 4.60
Infiltration Detection—Ceiling Seams and Exterior Door

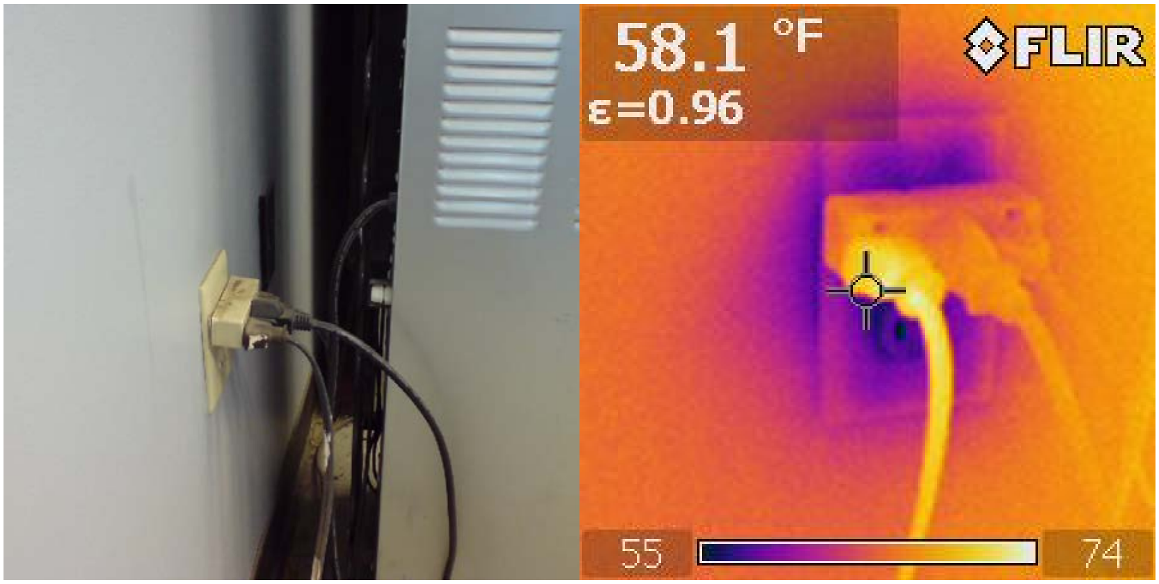

FIGURE 4.61
Infiltration Detection—Electrical Outlet

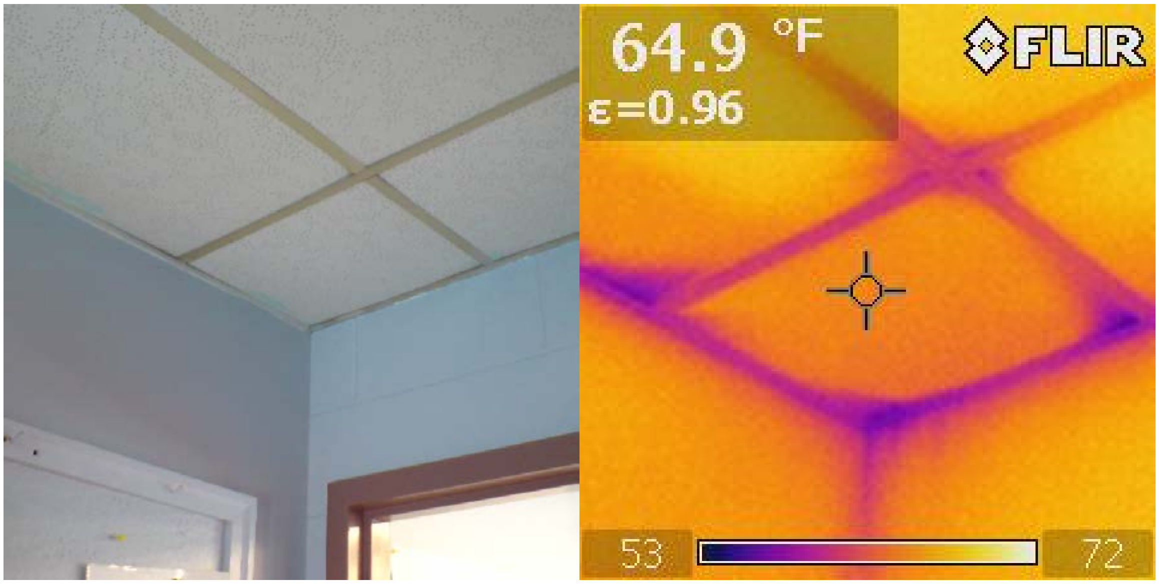

FIGURE 4.62
Infiltration Detection—Ceiling Grid Seams

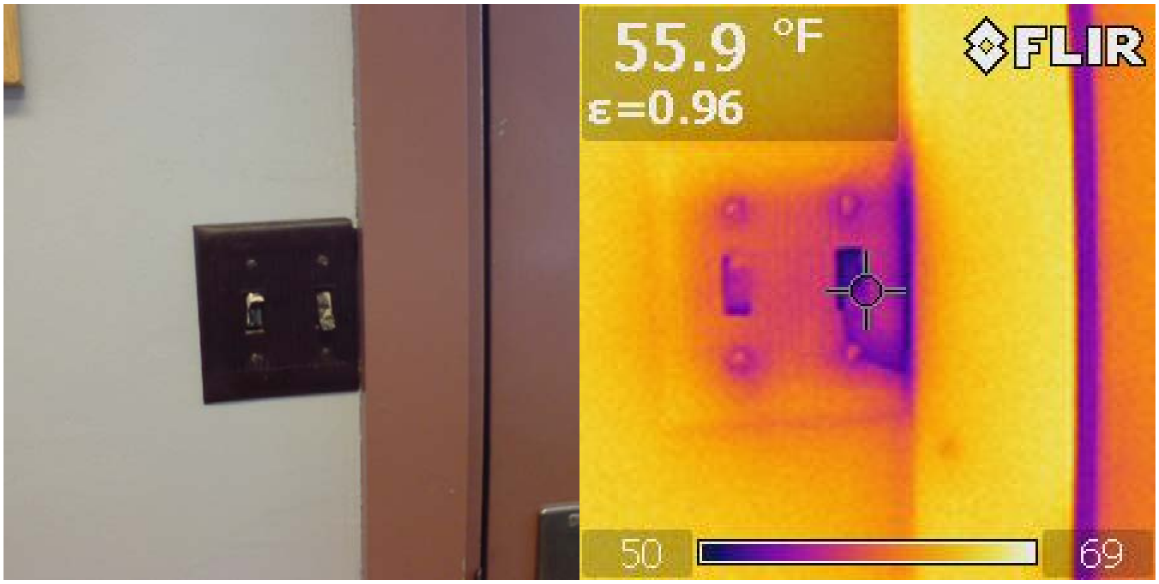

FIGURE 4.63
Infiltration Detection—Light Switch

Table 4.3 summarizes the six audited KDOT facilities and the information gathered on the audit worksheets, which can be found in Appendix C.

TABLE 4.4
Facility Summary—Measured and Recommended Values

	Interior Lighting (fc) (Office & Storage Spaces)		**LPD (W/SF)**	**Water Discharge Temperature (F)**		**Programmed Thermostat Set-Points (F)**	
Facility	Measured	Recommended	Measured	Measured	Recommended	Measured	Recommended
Atchison	6.0 - 42.5	Office Spaces 30 – 50 fc	1.322	**117.1°**	110°	**72° HTG** **70° CLG**	68° HTG 78° CLG
Belleville	**11.4 – 111**		1.245	**141.5°**		**69° HTG** **75° CLG**	
Russell	**8.6 – 65**		0.421	104.1°		**68° HTG** **74° CLG**	
Altamont	**42 – 130**		0.211	**114.4°**		N/A, PTAC Units	
Larned	**9.6 – 128**		0.612	108.1°		**70° HTG** **70° CLG**	
Jetmore	**14 – 146.8**		0.705	**117.3°**		**66° HTG** **72° CLG**	

Note: Bolded values are above the recommended value and indicate a problematic area.
HTG: Heating, CLG: Cooling

4.5 Specific Recommendations for All KDOT Facilities

After auditing the six selected facilities, a list of common recommendations was developed. All of these options should be considered when renovating KDOT facilities or purchasing new equipment. In Chapter 6, “Overall Cost Analysis,” the life-cycle-cost and rate of return is calculated for the items and recommendations discussed within this section.

It is recommended that all single-pane windows be replaced with double pane windows to reduce heat gains and losses. Based on Table 5.5-4 and Table 5.5-5 in ASHRAE Standard 90.1-2010, the shading coefficient, or thermal insulating performance, for all glass should be a maximum of 0.40 for both climate zone 4A and 5A. The maximum U-value, or the amount of heat transfer as a result of conduction, for all glass should be between 0.40 and 0.55 for climate zone 4A, and between 0.35 and 0.55 for climate zone 5A, depending on the window construction (ASHRAE, 2010). Weather strip, seal, and caulk should be installed at all windows and doors to reduce infiltration to the facility. Furthermore, caulk should also be installed around building seams, walls, ceilings and any other exterior penetrations. Insulated doors, with a maximum U-value of 0.70 should be installed between places with substantial temperature difference to reduce heat gains and losses (ASHRAE 2010). The location of this occurrence would be exterior doors or the door between the semi-heated shop space and the office space.

In regard to lighting, energy-efficient lamps should replace the current lamps, both interior and exterior, unless T5s are already present. Incandescents should be replaced with compact fluorescents. The following linear fluorescent lamps are listed in order of decreasing efficiency: T5HO, T5, T8, and T12s. Linear fluorescents can also be identified by their diameter as shown in Figure 4.23. It should be noted that a lamp's ballast continuously draws power whether the lamp is on or burnt out. Therefore, instead of intentionally not replacing lamps with the intention of saving energy the fixture should instead be replaced to house fewer lamps. To confirm the energy saving capabilities of linear fluorescent lamps, lamp type, light power density (LPD) measured in watts per square foot (W/sf) and electricity use/area measured in kilowatt-hours per square foot (kWh/sf) were compared. Within Appendix E, Tables E.15 and E.16 outline the calculations and numerical results for the comparison. It was found that the more efficient lamps had a lower LPD and therefore a lower energy use per total square foot. For example, the Russell facility primarily utilizes T5HO lamps and had a LPD of 0.459 W/sf with an electricity usage of 0.140 kWh/sf. When compared to a facility, such as Atchison, that uses T12s and incandescents, the energy savings are very apparent. Atchison has a LPD of 0.981 W/SF and an electricity usage of 0.341 kWh/sf; more than double the values and energy usage of Russell. Another energy saving measure is to avoid over-lighting a building, such as the Belleville facility. The facility had a range of light level readings from 85-111 footcandles, when office spaces generally require 30-50 footcandles of light according to the IESNA Guidebook, occupants will still remain productive with the recommended lighting levels, while saving electricity usage.

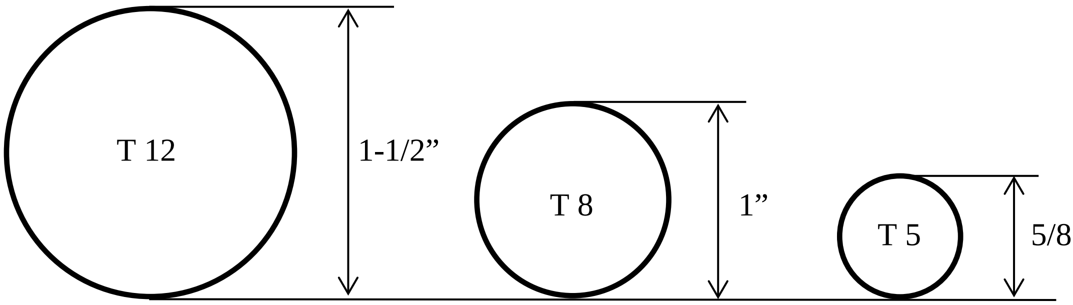

FIGURE 4.64
Linear Fluorescent Diameter Comparison

Lighting controls should be upgraded as the light fixtures are upgraded. One option is to install occupancy sensors in the office spaces to ensure that the lights are turned off when the spaces are not occupied. The second option is to install a time clock system that will automatically turn lights on and off in the office areas at designated times. This will ensure that the lights will not be left on overnight or on the weekends. Both control options will save energy consumption; therefore facility managers could choose either system, focusing on personal system preference or financial feasibility. Facilities audited had photocell sensors for the exterior lighting; however, these photocells should be tested to ensure that they are fully functioning and adequately controlling the exterior light fixtures. Another aspect of lighting controls involve exhaust fans and restroom lighting. Many facilities had the restroom lights directly connected to the exhaust fan, causing excess energy usage when fan operation is not desired.

Programmable thermostats should be installed in all facilities and the facilities with this style of thermostat already installed should use the programming function. In more than one facility, the programming function was available but not used. This will allow for setbacks to reduce energy consumption when the building is unoccupied. Set points for the thermostat during occupied times need to be established for each season to be both realistic and energy efficient. The DOE suggests a winter thermostat setting of 68°F and a summer setting of 78°F with a setback/setup of 10-15°F in unoccupied mode in order to save around ten percent a year on heating and cooling bills (Department of Energy 2011). Also, all supply ductwork should be sealed to minimize leakage (ASHRAE 2010). Supply ductwork located in unconditioned areas, such as under the floor, need to be insulated with an R-3.5 insulation to help reduce heat loss and gain, as well as air loss and condensation (ASHRAE 2010).

In addition, water heaters should be sized based on a realistic daily use, using an accepted method from American Society of Plumbing Engineers (ASPE) or ASHRAE. Based on water consumption at the six audited KDOT subarea facilities and based upon one public lavatory and one service sink, all water heaters need to be capable of producing eight gallons per hour (GPH) of hot water or switch to instantaneous water heaters. Instantaneous water heaters are more energy efficient because there are no stand-by losses attributed to the hot water being generated and stored for long periods of time. Table 4.5 shows the calculation based upon the number of lavatories and service sinks at a facility, then multiplies the total GPH of each fixture by the demand factor given in the ASHRAE Handbook for an office space. The total value required is the value to be used to size and select the proper water heater.

TABLE 4.5
Hot Water Heater Sizing

Fixtures	Quantity	GPH/Fix	Tot GPH	Demand	GPH RQD	
Lavatories	1	6	6	0.3	1.8	
Janitor Sink	1	20	20	0.3	6	
					7.8	GPH

If changing the water heater to point of use or instantaneous, any recirculation pumps associated with the old system can be removed, allowing for additional energy savings. The water discharge temperature should be decreased to a maximum of 110 degrees Fahrenheit for public use lavatories, per ASHRAE Standard 90.1-2010, to reduce energy consumption and eliminate the risk of scalding.

Another method to ensure water consumption savings is to install efficient, low-flow, low-water consumption plumbing fixtures. From the Energy Protection Act of 2005, the flow rates of public fixtures are governed to be maximums of 1.6 gallons per flush (GPF) for water closets, 0.5 gallons per minute (GPM) for lavatory faucets, and 1.0 GPF for urinals. The lower the fixture values of GPF or GPM, the quantity of water consumed can be reduced and the savings on water utilities increased.

Lastly, appliances that are Energy Star certified should be installed when possible to create additional building savings. Energy Star certified equipment is rated by the governmental program to identify equipment with reduced energy consumption and emissions. Energy Star ratings are provided on labels affixed to equipment and appliances. Select appliances that are above the average, as shown on the label. These appliances include the furnaces, water heaters, refrigerators, computers, printers, etc.

Chapter 5: Energy Star Portfolio Manager

Kansas Statute 1-66-2 stipulates that for every state agency owning real property, the agency head, or that person's designee, must conduct an energy audit of each building on that real property and submit a written report regarding the energy audit. The statute further stipulates energy audits must be conducted every five years for each building. The statute defines an 'energy audit' as "the utilization of a building energy-use benchmarking system, including the energy star portfolio manager, that generates a written report that details the conversion of a building's energy consumption data into energy-intensity metrics for the purpose of comparing the energy use of a building to the national average energy use of similar buildings." The purpose of this statute is for the state agency, in this case, KDOT to analyze the monthly amount of energy consumed in the preceding 12-month period as recorded by utilities selling energy or water services. The audits must look at the buildings for an "excessive amount of energy," which is determined by comparing the building's site and source energy-intensity metrics, annualized to a 12-month period, to the national average site and source energy-intensity metrics of similar buildings. If the site and source energy-intensity metrics of the building subject to an energy audit are greater than the national average site and source energy-intensity metrics, then the building shall be deemed to use an excessive amount of energy.

Since the Energy Star Portfolio Manager is mentioned specifically in the regulation, this chapter briefly explains what Portfolio Manager is, what it does, and how KDOT facilities can use it for energy management. Detailed procedures on how KDOT facilities would import data into the Energy Star Portfolio Manager can be found in Appendix E.

Energy Star's Portfolio Manager is an online energy management tool created by the United States Environmental Protection Agency that uses an algorithmic formula for tracking and assessing energy and water consumption across a portfolio of buildings. This online tool is used by more than 200,000 commercial buildings to track their energy and water use and to make strategic decisions in regard to reducing their consumption.

Using Energy Star Portfolio Manager allows an organization to –

- Benchmark energy use
- Determine the energy use intensity (kBTU/ft2) for each building

- Track changes in energy and water use over time for each building, group of buildings, or over an entire portfolio
- Compare one building against a national sample of similar buildings
- Compare buildings of a similar type to each other, and
- Set priorities for use of staff time and/or investment capital.

More specifically, using the Energy Star Portfolio Manager, KDOT will be able to do the following:

1. Assess energy performance of individual buildings, as well as the group of buildings altogether. Portfolio Manager allows this by ensuring KDOT establishes an energy baseline for each building, from which KDOT managers can set goals for energy improvement and track and measure their progress towards those goals over time.
2. Identify best opportunities for energy efficiency improvements. By comparing the energy use intensity of each building to one another, KDOT managers can select the buildings with the highest energy use intensity to focus its resources and energy management efforts. It also allows KDOT to take the buildings with the least energy use intensity and apply the best management practices used by those buildings and apply them to buildings with higher energy use intensity.
3. Track progress over time. The Portfolio Manager allows KDOT to set an energy baseline and monitor energy efficiency improvements over time. Through Energy Star graphics, KDOT will be able to visualize the percent improvements in weather-normalized energy use intensity. In addition to tracking energy usage, Portfolio Manager also includes emissions from the electric power utility and allows KDOT to monitor reductions in greenhouse gas (GHG) emissions, while monitoring energy and water usage at the same time.
4. Document energy savings results. The Portfolio Manager software provides transparency and accountability to demonstrate strategic use of capital improvement funding by quantifying and accurately documenting energy savings for an individual building or for an entire portfolio of buildings. The program also allows KDOT to download performance metrics from Portfolio Manager and import the data into Excel.

Portfolio Manager generates a default Statement of Environmental Performance (SEP) for each building, but also allows KDOT to create tailored views from 70 different data columns and generate custom reports.

There are four basic steps to using Portfolio Manager – 1) Creating/editing a Portfolio Manager account, 2) adding/editing separate properties, 3) adding/editing separate spaces, and 4) adding/editing energy meters for each energy use (e.g., electricity, natural gas). As mentioned above, Appendix E walks through the process of using the Energy Star Portfolio Manager.

Although establishing an energy baseline is Energy Star Portfolio Manager is useful and one can determine a facility's energy consumption to other, similar facilities on a nation-wide basis, the true robustness of the program comes from maintaining the data input and using the program to manage all of an organization's energy consumption. Consequently, it is critical to input electricity, natural gas, and water consumption on a periodic basis. Most commonly, the most efficiency method is to enter utility data monthly as it is received. KDOT should develop a strategy and a written procedure for individual facilities to accomplish this data input.

Portfolio Manager allows a couple of scenarios for this monthly input. One option is for a designated person at each individual facility to enter the data as the utility bills are received at the facility. Portfolio Manager has a mechanism by which all of the individual facilities can then share this information with a KDOT representative with overall responsibility for KDOT energy management. The KDOT representative can then run reports on all of the KDOT facilities in each of the districts. A second option is to make the overall KDOT energy representative, or his or her designated representative, a Master Account holder. Master Accounts are designed for those users of Portfolio Manager that need to oversee or access large portfolios of facilities, typically owned or managed by several different individuals or organizations. The Master Account makes it easier for users to share a set of facilities with the Master Account holder. By identifying your account as a "Master Account", other users who want to share facilities with you through Portfolio Manager will be able to view and select your user and organization name during this process. This eliminates the need for you to have to provide this information to every individual or organization you work with by, instead, simply allowing them to select your user and organization name from a list when they go to share their facilities with you. Appendix E provides additional information on each of these options.

Chapter 6: Overall Cost Analysis

The energy audits of the six KDOT facilities, discussed in Chapter 4, highlighted many possible changes to improve energy efficiency. The recommendations include: replacing windows with double-pane windows, sealing all penetrations in the building, replacing doors that divide spaces with high temperature differentials, replacing lighting fixtures and lamps to more energy efficient fixtures, utilizing lighting controls, installing and using programmable thermostats, sealing and insulating ductwork, installing water heaters sized for the actual demand, installing low-water consumption and low-flow plumbing fixtures, and using Energy Star certified appliances. In order to determine the cost justification of improvements and to determine the changes to schedule and finance first, the net present cost for each of the recommended changes must be calculated.

Calculating the life-cycle-cost for recommendations was done using net present cost, NPC. To calculate the NPC of each proposed alteration, the first cost and annual maintenance cost for the life-cycle were calculated using traditional economic formulas found in Table E.5 of Appendix E. Annual operating costs and utility costs were calculated based on the average utility rates for the KDOT facilities and using product energy data and energy modeling. If there is a demolition cost for the existing item, this cost was also included in the calculations. To assist in pricing, 2012 RS Means Cost Data manuals were utilized to find the average initial, operating, maintenance, salvage, and demolition costs, which can be found in Appendix E, Tables E.1 through E.4. For the calculations, an interest rate of 6% was assumed, as well as a life-cycle of 20 years. A spreadsheet was developed specifically for the analysis of NPC and return on investment, ROI, for the KDOT facilities for most recommendations (the operable spreadsheet was provided directly to KDOT separate from the report). Referencing the calculation spreadsheet graphic in Figure 6.1, all parameters can be adapted to the appropriate interest rate and life-span per calculation. Each cost parameter can be filled in within the operable spreadsheet and the NPC is calculated.

The next calculation to be performed is the return on investment, ROI. ROI is calculated by comparing the current item with the recommended replacement item; for example, comparing the existing T12 lamps with new T5 lamps. The process of calculating the NPC and the ROI for replacing a 30-gallon natural gas water heater with a 3.2 GPM instantaneous natural gas water heater is shown below. As stated before, the values used in the example were found within the 2012 RS Means Cost Data manuals.

Net Present Cost Calculation
Replacement of a 30-Gallon, Natural Gas with a 3.2 GPM Instantaneous Natural Gas Water Heater

Item's First Cost	$ 749.00
Annual Maintenance Cost:	$ 0.61
Annual Energy Cost:	$ 59.00
Demo Cost:	$ 71.50
Salvage Cost:	$ -

Life: 20 Yrs
Interest Rate: 6 %

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

NPC = **$ 1,203.41**

Definitions/Assumptions:

First Cost: Initial Cost of Equipment for Purchasing and Installing
Annual Maintenance Cost: Annual Costs Associated with Maintenance
Annual Energy Cost Difference: Difference between existing cost and new annual energy cost
Demolition Cost: The cost at the end of an item's life to remove it
Salvage Cost: When an item has died and requires replacing, this is the value of the salvaged parts.
Electricity: Assumed rate of $0.07 kWh. Use regional applicable rate.
30-Gallon Heater: Initial Cost = $ 3162.00 and Annual Costs = $ 160.00
3.2 GPM Instant Heater: Initial Cost= $ 749.00 and Annual Costs = $59.00
Water Heater Annual Costs calculated through Department of Energy

Economic Analysis Equations: (Stokes, 2012)

P: Present Cost, F: Future Cost, A: Annual Cost, i: Interest Rate, n: Years

Present Cost given Future Cost: (P/F, i, n) = F * (1+i)^n

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

Return on Investment

$$\text{ROI} = \frac{\Delta A}{\Delta P} = \frac{\text{(Difference in Annual Costs)}}{\text{(Difference in Initial Item Costs)}}$$

$$\text{ROI} = \frac{\Delta A}{\Delta P} = \frac{(160.00-59.00)}{|(3162.00 - 749.00)|}$$

ROI = **4.19 %**

Payback Period

$$\text{Payback} = \frac{\Delta P}{\Delta A} = \frac{\text{(Difference in Initial Item Costs)}}{\text{(Difference in Annual Costs)}}$$

$$\text{Payback} = \frac{\Delta P}{\Delta A} = \frac{|(3162.00 - 749.00)|}{(160.00 - 59.00)}$$

Payback = **23.89** years

FIGURE 6.1
Calculations for Net Present Costs and Return on Investments

The NPC and ROI values for each of the other facility energy saving recommendations can be found in Tables 6.1, 6.2, 6.3, 6.4, 6.5 and 6.6. The detailed calculations and any assumptions made for potential upgrades, as walked through in the example above, can be found in Appendix E.

In order to select the feasible recommendations and changes for KDOT facilities, the NPC and the ROI values must be taken into account. Once these values are calculated for the different possible improvements, they must be compared to determine the best option. To better understand what the calculated values are indicating, there are a few guidelines to follow. The lower the NPC, the lower the overall cost of the item over its lifespan. Next, the higher the ROI value, the sooner the cost will be recovered. The ROI value represents how long it will take to recover the cost of replacing the current system. The payback period is the inverse of the ROI and depicts how long it will take to recover the cost, in terms of years.

If there are multiple options being considered, it is important to select the item with the lowest NPC as well as highest ROI. If an item does not have the best value in both calculations, then the organization must decide which aspect is more important – overall cost, or recovering costs.

By using the information in Tables 6.1 through 6.6, the viable recommendations can be determined. Windows should be replaced with double-pane windows, since the NPC of all three double-pane options is lower than the single-pane windows and have low ROI values.

TABLE 6.1
NPC - Single-Pane Windows and Doors

Item	Net Present Cost
Aluminum Windows, Single-Pane	$14,762.01
Steel Windows, Single-Pane	$14,686.01
Wood Windows, Single-Pane	$13,599.02
Interior Metal Door	$509.95
Exterior Metal Door	$588.45

TABLE 6.1
NPC and ROI—Double-Pane Windows

Item	Net Present Cost	Return on Investment	Payback Period
Aluminum Windows, Double-Pane	$11,478.03	Between Single Pane and Double Pane: 191%	Between Single Pane and Double Pane: 0.52 years
Steel Windows, Double-Pane	$11,347.03	Between Single and Double Panes: 294%	Between Single and Double Panes: 0.34 years
Wood Windows, Double-Pane	$9,062.05	Between Single and Double Panes: 784%	Between Single and Double Panes: 0.13 years

Thermostats should be replaced with programmable low voltage thermostats, either two or three wire, since those items have low NPC. Both of the low voltage thermostats would satisfy a facilities needs; however, the three-wire thermostat has been proven to take more accurate temperature readings.

TABLE 6.3
NPC—Thermostats

Item	Net Present Cost
Thermostat, 24 hour, Automatic	$188.50
Thermostat, Low Voltage, 2 Wire	$63.50
Thermostat, Low Voltage, 3 Wire (More accurate thermometer)	$71.50

The linear fluorescent light fixtures need to be replaced with T5 and T8 fluorescent fixtures and lamps. Starting in July 2010, many of the ballasts associated with T12 lamps stopped being produced. The T12 lamps as of July 2012 are also being phased out of production (Green Savings Company 2012). KDOT will recover the first costs quickly due to the ROI value being positive value. The NPC is similar between T5 and T8 lamps and fixtures, so either is a viable option from a financial standpoint. Facilities with T12 lamps should upgrade to either T5 or T8 lamps depending on availability, and facilities with T8 lamps can upgrade to T5 fixtures when finances allow, reducing energy consumption even more. Due to the increasing stringency of energy codes, it is recommended that KDOT move towards the utilization of T5 lamps and fixtures. It is important to note that lamps cannot be changed without at least changing the ballasts and in many cases it may be more advantageous to replace the entire fixture. The ballasts deliver power to fluorescent lamps and are not interchangeable between lamp types. To decide whether the ballasts or entire fixture should be exchanged will depend on available budget dollars. The facility manager will want to determine the price of replacing the ballasts and purchasing new lamps and compare to purchasing a completely new fixture and lamps.

For light fixtures that are currently using incandescent lamps, it is recommended to trade the lamps for compact fluorescents (CFL). The ROI for replacing incandescents with CFLs is 1280%, making the upgrade a viable option and an immediate payback. Ballasts do not need to be added because the CFL's have integral ballasts.

An additional energy saving measure would be to reduce lighting levels in some facilities. If upgrading the light fixtures, choose a fixture with fewer lamps to reduce energy consumption, while still maintaining adequate task lighting. IESNA recommends 30-50 footcandles within an office environment. It might be advantageous for the facility manager to contact a design engineer prior to adjusting lamp quantities and light levels for major renovations. Another method would be to remove a lamp from the existing fixture, making sure to disconnect the corresponding ballast if possible since it continuously draws power whether a lamp is present or not.

TABLE 6.4
NPC and ROI—Lights and Lamps

Item	Net Present Cost	Return on Investment	Payback Period
Fluorescent 4' Strip Fixture, T8 (30W)	$66.07	Between T12 and T8 lamp: 60%	Between T12 and T8 lamp: 1.68 years
Fluorescent 4' Strip Fixture, T5 (28W)	$64.36	Between T12 and T5 lamp: 103%	Between T12 and T5 lamp: 0.97 years
Compact Fluorescent (25W)	$84.40	Between Incandescent and CFL lamp: 1280%	Between Incandescent and CFL lamp: 0.08 years
Incandescent A-Lamp (100W)	$283.99	--	--

To help seal the building and prevent outside air from entering into the building, all exterior penetrations should be sealed. From Table 6.5, the recommended item would be latex caulk since it has the lowest NPC.

TABLE 6.5
NPC—Joint Sealant

Item	Net Present Cost
Latex Caulking (1/4"x1/4")	$7.89
Latex Caulking (3/8"x3/8")	$8.08
Polyurethane Caulking (1/4"x1/4")	$7.96

Lastly, water heaters should be replaced with a smaller, instantaneous model of the same utility. Therefore, thirty gallon electric water heaters should be replaced with 8-GPH instantaneous electric water heaters or five-gallon electric point-of-use water heaters. Natural gas thirty gallon water heaters should be replaced with 8-GPH instantaneous or natural gas point-of-use water heaters. From collected data at the individual KDOT facilities, the sub-area buildings do not have enough hot water demand to warrant a water heater more than eight-gallons. Table 6.6 displays the NPC and ROI for suggested water heaters compared to the typically installed thirty gallon natural gas heater. The calculated values do not include additional wiring, breaker size upgrade, or other electrical components possibly required. Before exchanging the current water heater for an electric option, the electrical panel size and breaker space need to be considered and availability confirmed. The values in the table may not indicate a viable option; however, when considering the utility available at the facility and the sizes of water heaters available, ROI and payback should be calculated in order to make the best selection for the facility.

TABLE 6.6
NPC and ROI—Water Heaters

Item	Net Present Cost	Return on Investment	Payback Period
Five-Gallon Electric Water Heater	$4,429.21	Between 30-Gallon NG and Five-Gallon Electric: -4%	Between 30-Gallon NG and Five-Gallon Electric: 0 years
Ten-Gallon Electric Water Heater	$6,766.74	Between 30-Gallon NG and Ten-Gallon Electric: -59%	Between 30-Gallon NG and Ten-Gallon Electric: 0 years
Six-Gallon Instantaneous Electric Water Heater	$2,687.21	Between 30-Gallon NG and Six-Gallon Instant Electric: -1%	Between 30-Gallon NG and Six-Gallon Instant Electric: 0 years
Ten-Gallon Instantaneous Electric Water Heater	$4,814.74	Between 30-Gallon NG and Ten-Gallon Instant Electric: -9%	Between 30-Gallon NG and Ten-Gallon Instant Electric: 0 years

After conducting the six building energy audits, reoccurring problems were found and recommendations made. The recommendations included replacing single-pane windows with double-pane windows, sealing all penetrations in the building, replacing ill-fitting doors, replacing lighting fixtures and lamps to more energy efficient fixtures, installing lighting controls and mechanical controls, sealing and insulating ductwork, installing practical water heaters, installing low-water consumption and low-flow plumbing fixtures, and using Energy Star certified appliances. By implementing all of these changes and balancing the net present cost and return on investment values, the energy consumption of each facility can be reduced and the efficiency increased.

Chapter 7: Carbon Footprint and Utility Consumption Reduction

The carbon footprint, a total summary of greenhouse gas emissions, was calculated from the individual building's electricity, natural gas and water usage with the utility data collected in Phase 1 of this project. To calculate a carbon footprint value that could be compared between different utilities, the consumption value was multiplied by a conversion factor to Metric Tons CO_2, as shown in Table 7.1. Table 7.2 has the calculated carbon footprint values for 2010 on each of the six KDOT facilities that were audited.

TABLE 7.1
Carbon Footprint Emission Factors from Phase 1

Final Factors	
Electricity	0.0007089235515 Metric Ton CO2/kWh
Natural Gas	0.0053196000000 Metric Ton CO2/therm
Water	0.0000023394360 Metric Ton CO2/Gallon

TABLE 7.2
Carbon Footprint for 2010 from Phase 1

2010 Electricity Carbon Footprint			
District	City	Consumption (kWh)	$MTCO_2e$
1	Atchison	43740	31.008
2	Belleville	50560	35.843
3	Russell	20209	14.327
4	Altamont	18747	13.290
5	Larned	31726	22.491
6	Jetmore	15080	10.691

2010 Natural Gas Carbon Footprint			
District	City	Consumption (therms)	$MTCO_2e$
1	Atchison	3775	20.081
2	Belleville	4800	25.534
3	Russell	4990	26.545
4	Altamont	5650	30.056
5	Larned	3911.5	20.808
6	Jetmore	2485	13.219

2010 Water Carbon Footprint			
District	City	Consumption (gallons)	$MTCO_2e$
1	Atchison	101593.36	0.238
2	Belleville	140500	0.329
3	Russell	43100	0.101
4	Altamont	65000	0.152
5	Larned	95000	0.222
6	Jetmore	116000	0.271

2010 Overall Carbon Footprint		
District	City	$MTCO_2e$ Totals
1	Atchison	51.327
2	Belleville	61.706
3	Russell	40.972
4	Altamont	43.498
5	Larned	43.521
6	Jetmore	24.181

KDOT can reduce their carbon footprint significantly by making the changes recommended in Chapter 6. While the reduction in carbon footprint is an estimation, any universal changes that KDOT can implement will have a large impact on the 157 facilities within their responsibility. Since energy codes increase in stringency every edition, if KDOT were to adhere to the requirements of ASHRAE Standard 90.1-2010 and continue to improve in the future, KDOT facilities can continue to decrease their carbon footprint throughout Kansas. Even small changes, such as changing lamps to higher efficiency lamps can have a large impact on the carbon footprint.

To demonstrate the reduction in carbon footprint from just two simple adjustments, the following calculation was performed. The calculation focuses on Atchison's building utility usage to act as an average for all KDOT buildings because the Atchison facility had improvement needs similar to the other five buildings that could be addressed as a benchmark for other facilities. The first renovation item addressed was lighting. Atchison had 172 linear fluorescent lamps, 30-60W incandescents and five 100W incandescents. When changing from 54W T12 linear fluorescents and 60 or 100W incandescents, to 28W T5 linear fluorescents and 25W compact fluorescents, a significant amount of electricity was saved. With the assumption of 365 days of operation at 8 hours per shift a day, electricity usage was reduced by 25,829 kWh, while maintaining the same light level. The next building adjustment was the utilization of programmable thermostats with set-backs. With a simple set-back program outlined in the recommendation section earlier, ten percent of heating and cooling usage, or 377.5 therms and 4340 kWh can be saved (Department of Energy 2011). This translates to a ten percent reduction in natural gas (heating) and electricity (cooling) usage with the assumption of a natural gas furnace for heating as found in most of the facilities. Implementation of just these two simple recommendations in Atchison could result in a fifty percent reduction in carbon footprint. Table 7.3, depicts the carbon footprint savings just described. To calculate an all-encompassing carbon footprint analysis, all building modifications should be included. Though, the calculation performed in the report does not include other possible carbon footprint reductions for recommendations such as window replacement, water heater exchanging or sealants. Each of these recommendations would further decrease the carbon footprint of the facilities; however, the utility consumption for each item would be difficult to trace back to utility energy usage. Therefore, the calculation presented takes a conservative approach to the possible carbon footprint reductions possible.

TABLE 7.3
Carbon Footprint Atchison Savings

Atchison Carbon Footprint - Pre-Improvements		
Energy Type	**Consumption**	**MTCO2**
Electricity, 2010 (kWh)	43740	31.01
Natural Gas, 2010 (therms)	3775	20.08
Water, 2010 (gallons)	101593.36	0.24
Total		51.33

Atchison Carbon Footprint - Post-Improvements		
Energy Type	**Consumption**	**MTCO2**
Electricity (kWh)	13571	9.62
Natural Gas (therms)	3397.5	18.07
Water (gallons)	101593.36	0.24
Total		27.93

Percentage Difference	54.41%

Utility Savings	**Consumption Difference**	**Budget Savings**
Electricity ($0.07/kWh)	30169 kWh	$ 2,111.83
Natural Gas ($0.60/therm)	377.5 therm	$ 226.50

Total Utility Budget Savings	$ 2,338.33

Chapter 8: Conclusion / Implementation Recommendations

KDOT desires to reduce the energy consumption and the carbon footprint of its facilities. In order to do so, the efficiency of the facilities must be improved. The research conducted in Phase 2A determined a minimum acceptable level of construction and operation for KDOT facilities, established an energy audit procedure, and recommended improvements to existing facilities.

In order to suggest changes and improvements to new and existing KDOT buildings, a baseline needed to be selected. After examining industry accepted codes and standards, the codes of surrounding states and the determinations of the Department of Energy, ASHRAE Standard 90.1-2010 was selected to be the baseline, the minimum acceptable requirements for construction and renovation. ASHRAE Standard 90.1-2010 applies to all KDOT facilities, including both new buildings and renovations to existing buildings. ASHRAE Standard 90.1-2010 establishes requirements for all aspects of the building, specifically the building envelope, the HVAC system, the electrical and lighting systems, and the domestic hot water system.

Once ASHRAE Standard 90.1-2010 was selected as the minimum acceptable requirements for energy, an energy audit procedure was created in order to survey and compare the existing facilities to the baseline. Six KDOT facilities, one from each district, were then audited using the procedure. The facilities selected were the subarea buildings in Atchison, Belleville, Russell, Altamont, Larned, and Jetmore. From the data collected during the audits, changes were recommended in order to increase the efficiency of each facility.

The NPC and the ROI were calculated for each recommended change in order to determine which recommendations were feasible. The final recommended changes include installing double-pane steel or aluminum windows, installing programmable low voltage thermostats, upgrading to T5 lamps and fixtures, downsizing to either instantaneous water heaters or six-gallon point of use small capacity storage water heaters, and caulking and sealing.

Further recommendations include the continual auditing of KDOT facilities. Each facility should be audited once every two years. In doing so, any problems such as air leakage, burned out lamps, or equipment malfunction will be detected and can be fixed before significantly reducing the building’s overall efficiency. The audit procedure, worksheets, spreadsheets, and

Excel document should be used to audit in each facility. Appendix B can be printed and used each time an audit needs to be conducted. By using the resources in Appendix B, the individual(s) conducting the audit can determine changes that can be made to reduce the energy consumption of the facility. Once possible changes are determined, the calculations in Chapter 6, Appendix E, and the Excel spreadsheet can be used to calculate the net present cost and return on investment for the changes. The facility can then select viable changes as discussed in Chapter 6.

In addition to the energy audits, utility data must also be catalogued. Since some of the individual facilities do not receive nor pay the utility bills, it is important to use a program such as Energy Star, which will allow for utility usage and cost to be recorded and the data accessed by multiple parties. In using Energy Star, the utility consumption and cost can be monitored by the facility, the district, or by KDOT as a whole. By tracking the utility data, outliers can be determined, whether it be a specific facility or a specific month, and changes can be made to reduce energy consumption and increase KDOT's overall building efficiency. Phase 1 established the Portfolio Manager for the KDOT facilities; however, KDOT needs to establish a system for the utilities to be continually added for each facility and the data analyzed.

As a final step, the carbon footprint and utility use reduction was estimated. In order to calculate an estimated reduction, energy saving was calculated for the suggested recommendations and improvements. Using the savings, the reduction in energy consumption was calculated and, with the formulas developed in Phase 1, the reduction in carbon footprint was calculated. It is estimated that the changes recommended for Atchison in Chapter 6 will result in a reduction of carbon footprint of over fifty percent, or $ 2,338, with the assumption of $ 0.07/kWh and $ 0.60/therm.

This was an analysis conducted on six facilities and it is shown that there is a decrease in carbon footprint but also decrease in energy use resulting in utility savings. If all 91 KDOT subarea facilities are similar to the Atchison facility, there is a potential annual energy savings of $ 212,755. There will need to be investment made to reach these savings but ultimately there can be a significant impact on long term budgetary savings. Changes and improvements are gradual and depend on the continual cycle of auditing and improving in relation to the baseline. In the future, a new baseline will need to be adopted as the building construction industry, equipment availability, and energy codes evolve. This report contains the necessary tools to implementing an auditing procedure, determining the crucial and feasible changes, monitoring the energy consumption and costs through the Energy Star Portfolio Manager, and eventually selecting a new set of minimum requirements for energy in order to reduce KDOT’s energy consumption and carbon footprint even further.

The Energy Star Portfolio Manager needs to be continually updated and the energy consumption monitored and tracked. In doing so, trends and outliers can be determined and addressed. Changes and recommendations need to be implemented to facilities. Once improved, the energy consumption of the facilities should be carefully tracked to calculate the actual reductions in energy consumptions. This would allow for additional energy consumption and carbon footprint calculations to be completed. Attention should also be given to the sustainable/green and high performance energy resources, such as ASHRAE Standard 189.1. These resources would allow for KDOT to reduce energy consumption and carbon footprint even more; however, meeting the requirements of the high performance standards may not be feasible or economically viable. More research would be needed to determine the next step for KDOT in terms of improving energy efficiency and reducing their carbon footprint.

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