PRESIDENT'S RESIDENCE ENERGY ANALYSIS

by

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A REPORT

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Abstract

The conservation of energy is an increasingly important issue. To raise awareness of energy conservation, the State of Kansas initiated the Take Charge Challenge, which focuses on energy conservation in homes across Kansas. The program pits city against city in a competition to determine which city can conserve the most energy in one year. In the spirit of friendly competition, Manhattan, Kansas, home of the Kansas State University Wildcats, and Lawrence, Kansas, home of the University of Kansas Jayhawks, competed in the Challenge during 2011. At the end of the Challenge, Kansas State was victorious saving a total of 5,783 million Btu (MMBTUs).

In the Spring of 2011, Noel Shultz, first lady of Kansas State University and co-chair of the Take Charge Challenge in Manhattan, set an example for other area residents by having an energy audit performed on her home, the historic Kansas State University President's Residence. The author used the audit, which was performed by an independent company, thermal images, a lighting survey, and various performance calculations to examine energy use in the building. The audit results include suggested improvements in order of importance. The suggestions were to install programmable thermostats, reduce air infiltration, and increase insulation. These improvements have the potential to provide a return on investment, although not all the suggestions are applicable to the home because of its historic nature. Other improvements, such as replacing lamps and insulating windows, were also researched by the author as means to reduce energy use.

This paper compares the audit results and the author's calculations to verify whether the suggestions are feasible and would provide a return on investment. Materials were donated by Kansas State University's Facilities Department for the improvements. Students and faculty volunteers participated in a work project to install the donated material. Only days after the insulation was installed, Mrs. Shultz mentioned that the family could feel an improvement in comfort. Thermal images of the roof verified that the insulation had reduced the heat loss. It is hoped that the improvements will also reduce energy consumption during the winter months.

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Chapter 1 - Residential Energy Consumption in America

Climate change and global warming are highly debated topics in the world today. In some instances, scientists can already measure the problems associated with these issues; in other instances, model-based predictions forecast where problems will occur. Whether or not these issues are real and measurable, it is general knowledge that the practices of industry and consumers today could be more environmentally-friendly. Our reliance on fossil fuels and the associated generation of green house gasses is impacting the environment.

Having identified the problem, the next step is to determine how to fix the problem. Terms such as 'green' and 'sustainable' are often used when discussing environmental problems. However, to the ordinary consumer, these issues seem so monumental that they do not see how making small changes will impact the world. The effect of these changes cannot be readily seen and are almost impossible to measure. If a family buys an electric car, the green house gases don't decrease by a measurable amount. It is easy for people to become discouraged at the perceived lack of improvement. Why spend money when there is essentially no pay back? Such an attitude ignores the cumulative impact of individual actions. If one person buys an electric car, and then everyone on their street buys an electric car, and everyone in the next town and next state and next country all buy and begin to drive electric cars, a measurable decrease in emissions would occur.

Unfortunately, expecting immediate, whole scale changes is not realistic. Even if everyone were educated on the environmental benefits of driving an electric car, everyone would not buy such a car, whether due to the price of the car or fears of untested technologies. So, although one family may buy an electric car for its environmental benefits, society must determine appropriate incentives for others to pursue actions that benefit the environment. The persuasion generally comes from a personal level instead of a global level. In many cases, by being environmentally friendly you can save money. Energy costs money so being energy efficient also means being efficient with money. Energy-saving measures will cost money initially but will save money as time goes on. So the payback on the investment is what will entice the common consumer. They are lured by the claim that even though they spend a few thousand dollars to install insulation, in the winter their heating bill will be reduced by hundreds of dollars. Additionally, by using less energy to heat their home they are also doing their part to help the environment.

A key component of getting the information to the consumer is marketing. If consumers can determine the payback of their investment before they buy a product, they will be more likely to purchase that product. Also, having multiple energy efficient choices is essential. EnergyStar is a company that has done well in marketing. Their home appliance seal has become essential to many consumers when buying a new refrigerator or television. Even the uninformed consumer may not know the specifics of a product, but if they see the EnergyStar seal they know that the product could save them money.

Companies like EnergyStar are relatively new to the consumer marketplace. Although EnergyStar began as a small company, as popular demand for EnergyStar products has grown, the company has expanded. An increasing awareness of energy usage can also affect all aspects of energy savings, not only appliances. For the residential market, people are becoming increasingly aware of energy efficiency and their home's energy efficiency. Even with energy efficient appliances, the focus may turn to making the energy efficient boiler work less by improving the shell of the house. The Take Charge Challenge competition in Kansas has undertaken such a goal and is teaching communities across Kansas how to save both energy and money by making their houses more energy efficient.

Take Charge Challenge

"As part of the American Recovery and Reinvestment Act (ARRA) of 2009, the State Energy Office received approximately $47.7 million in additional funding from the U.S. Department of Energy (DOE). (http://www.kcc.state.ks.us)." $38,284,000 of the funding went to the State Energy Program (SEP). The SEP used part of the funding to establish the Efficiency Kansas Loan program. The purpose of the loan program was to help train energy auditors and to market their services to the population of Kansas. Ultimately, the program would assist Kansans through loans needed to implement energy efficiency updates. The program also funded an extension of the Take Charge Challenge, another energy program, from the previous year.

"The Take Charge Challenge is an initiative of the Climate and Energy Project (CEP) (www.takechargekansas.org)." The CEP is a nonprofit organization that works to reduce emissions in the Midwest. The goal of the challenge was to prove that any area in Kansas, from rural to urban, could reduce energy use significantly by implementing energy efficient practices. Towns were chosen from across Kansas to participate in the Take Charge Challenge. Towns ranged from rural to urban and small to large. A leadership team of approximately fifty people was formed in each town. The leaders were to meet once a month. Each quarter they were responsible for hosting a party to engage the community and share the results of the previous month's energy savings. The competition and community aspect of the challenge helped to make it successful.

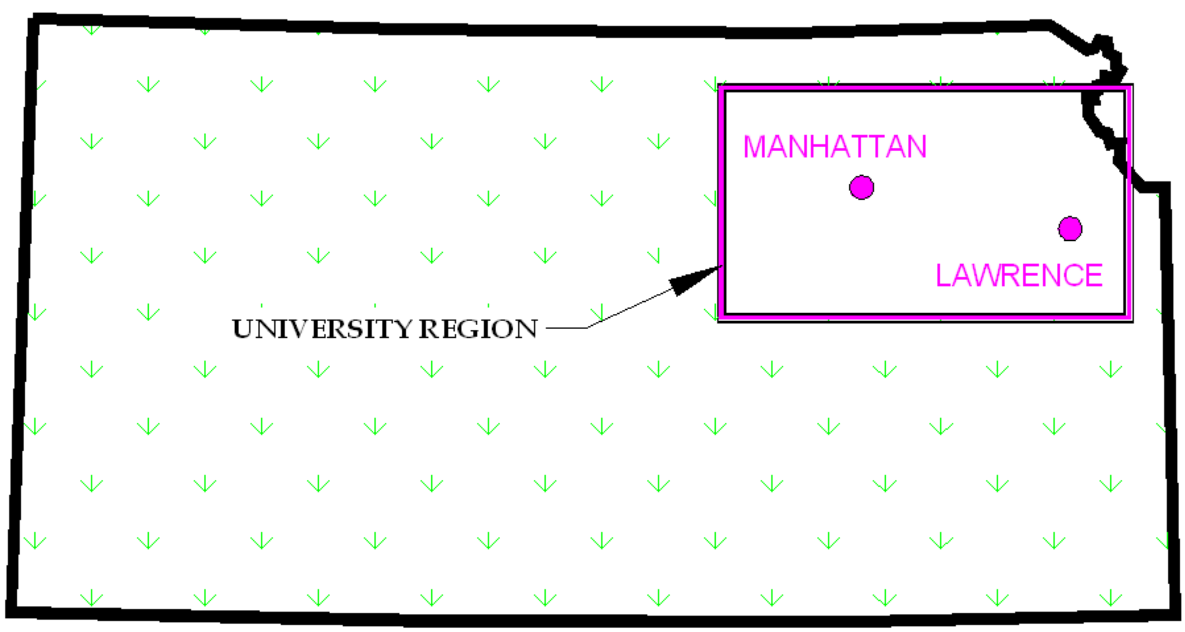
The competition compared two categories to determine the energy saved. First, it examined the actual kilowatt hours (kWh) savings of the town. A kWh is the amount of energy, or watts, consumed over the space of an hour. At the beginning of the program the local utility providers were informed about the project and were forthcoming with the required energy information. Comparing the energy consumption of a town to its energy consumption during the previous year was not reasonable because of the national economic downturn. There was some thought that families would already be trying to save energy to decrease their electric and heating bills when the economy was rough (Driving Demand). Therefore, towns were compared to other towns of similar size and demographics not competing in the Take Charge Challenge as the first assessment method.

The second method used to measure energy savings was an "estimated savings from prescriptive measures installed." These prescriptive measures included switching lamps from incandescent to compact fluorescent (CFL), replacing old appliances with EnergyStar rated appliances, installing programmable thermostats, and participating in home energy assessments, such as energy audits. Because these prescriptive measures have a payback period of multiple years, the forecast cost savings were used for the competition. Otherwise, the challenge would finish before the actual savings could be tallied.

After one year, the winning town for the first method reduced kWh by 5.5% compared to their baseline town, and the winning town for the second method reduced the town's electrical usage by 2.5%. The challenge was deemed a success with an estimate of at least 10,000 people actively involved in the process. Additionally, the challenge was highlighted as a best practice by the Lawrence Berkeley National Lab (LBNL) Electricity Markets and Policy Group (eetd.lbl.gov).

Following these efforts and using the funds from the State Energy Program, another Take Charge Challenge was initiated in 2011. The 2011 Challenge hoped to capitalize on the friendly competition of the previous year and specifically choose towns with long seated rivalries to compete against each other. Having an established rivalry, Manhattan, Kansas, home of the Kansas State University Wildcats, and Lawrence, Kansas, home of the University of Kansas Jayhawks, were chosen for the University Region component of the Take Charge Challenge. The competition commenced in January 2011 and continued through September 2011. The challenge included three categories that each measured different ways to save energy. Category 1 included home weatherization, Category 2 focused on switching lamps to compact fluorescent from incandescent, and Category 3 measured community involvement. At the conclusion of the competition the city who won two out of three of the categories would win the Challenge. In the event of a tie, the "categories would be weighted: five points for Category 1, three points for Category 2, and two points for Category 3" (takechargekansas.org). The competition is scored on a per capita basis so that a small city making the same number of changes as a larger city could win if the percentage of changes made to the small city is larger. For the University Region, Lawrence has a population of 92,048 and Manhattan has a population of 52,836 (takechargekanas.org). The winner of the Take Charge Challenge received a $100,000 grant to fund other energy efficiency projects.

Figure 1.1 Take Charge Challenge University Region



Category 1

Category 1 of the Challenge focused on energy efficiency retrofits made to homes and small businesses. Category 1 included Efficiency Kansas audits, completed Efficiency Kansas energy saving projects, Low-Income Weatherization Assistance Program (WAP) audits, and completed WAP projects. 50% of the estimated gas and electric savings from the Efficiency Kansas audits were awarded points once an audit was performed. 100% of the estimated savings in the audit were awarded points once the projects recommended in the audit were completed. Points were awarded by the amount of energy saved. Energy is measured in British Thermal Units (BTUs) and one point equates to one million BTUs (MMBTUs) saved. A city may, as an example, replace inefficient lamps in light fixtures with high-efficiency lamps to save energy. The BTUs saved will gain points for that city. A completed Efficiency Kansas project will supersede the Efficiency Kansas audit performed so that only 100% of the estimated savings were counted and not 150% (takechargekansas.org). The Efficiency Kansas retrofits and other energy efficiency measures must be completed within a year of the energy audit. The savings will be converted into MMBTUs by the CEP. The WAP audits and projects function in the same manner in that the energy savings are converted into MMBTUs.

Efficiency Kansas

Efficiency Kansas is a loan program developed by the Kansas Energy Office. It assists property owners in completing energy audits of their properties and then helps them finance loans to make the necessary changes listed in the energy audit in order to decrease their utility bills. Each audit lists the recommended energy saving projects in order of importance. Audits also include auditor estimates for the recommended projects. To be approved for financing, property owners must complete the projects starting with the first on the list. The rationale for requiring that the projects be completed in the recommended order is based on the "whole house" approach (Efficiency Kansas). The approach focuses on the fact that many different factors affect the energy performance of a home and it addresses the most critical needs first, which are not necessarily the most obvious By way of illustration, if a house is cold it does not immediately mean that a new furnace should be purchased. Instead, by completing an energy audit, it could be found that the furnace works well, but that air is escaping through an improperly sealed attic or chimney. Therefore, before a furnace is upgraded, sealing the attic or chimney must be completed first. Additionally, financing must be done though lenders or utilities that are partners with Efficiency Kansas. After the energy projects are completed on a property, the energy auditor will perform another inspection to ensure that all newly installed systems are working properly.

Weatherization Assistance Program (WAP)

The U.S. Department of Energy's Weatherization Assistance Program (WAP) helps low income households make energy efficiency changes to reduce their energy bills. To qualify as a low income household, the household income must be 200% of poverty level or below. "More than 40 million households are eligible for the weatherization services." (www1.eere.energy.gov). If a household qualifies, a trained weatherization crew will audit the house and determine solutions for improving its energy efficiency. During the audit, tools such as a blower door, manometer, and thermal camera are used for detailed and precise observations. The weatherization crew also performs safety checks of the household energy systems and looks for gas leaks and carbon monoxide. The program takes a whole house approach to decide which measures will be most cost effective. Common ways to improve the weatherization of a home are to install insulation, seal ductwork, decrease infiltration, and repair heating and cooling systems. A scale is used to determine how much money can be spent to upgrade a property and is dependent on the income of the residents. The services provided up to a scaled limit are free to the property owners. The calculated savings for the audit and associated upgrades are converted into MMBTUs when used in the Take Charge Challenge.

Category 2

Category 2 of the Take Charge Challenge focused on small scale energy efficiency measures rather than whole house renovations. These measures included replacing light bulbs, installing programmable thermostats, performing energy efficiency retrofits, and implementing measures suggested on the audit but not financed through Efficiency Kansas. For example, switching light bulbs from incandescent to compact fluorescent (CFL), or from T-12 to T-8 fluorescent lamps, gained 0.12 points per lamp. A T-12 lamp is older and less efficient than a newer, smaller T-8 lamp. Each programmable thermostat earned 1.81 points (takechargeKS.org). These changes were required to be recorded on the Take Charge website by the homeowner to count toward the competition. Such small energy efficiency measures are perhaps the easiest and least expensive way for community members to make energy efficiency changes to their homes.

Category 3

Category 3 of the Challenge was related to community involvement. The leadership team of each community sponsored community outreach events. Involvement at these events was measured based on the number of participants per capita. There were three levels of community involvement. The first level included presentations, trade show booths, and community challenge events. These events took the number of participants and multiplied by 0.1 to determine the number of points. The second level included teacher training by the Kansas Association Conservation Energy Educators (KACEE), KACEE activities in schools, real estate energy classes, and home energy audit classes. The multiplier was 10 times the number of participants for the second level.

The third and last level of community involvement was building operator certification classes, holding meetings leading to the voluntary adoption of energy efficient building codes, and holding Facility Conservation Improvement Program (FCIP) meetings. Only two meetings per quarter would count toward points but there was no limit to the points that could be earned through certification classes. Each of these events earned points equal to 100 times the number of participants. All events related to each of these levels were required to submit a record of attendance to the Regional Coordinator.

Results

After September 30, 2011, the results were tallied for the participants of Kansas's second Take Charge Challenge and the winners were announced. Kansas State University and the City of Manhattan beat The University of Kansas and the City of Lawrence to win the University Region rivalry. Challenge winners, including Manhattan, Baldwin City, Colby, and Fort Scott, each received a $100,000 grant to use for energy efficiency projects in their towns.

Manhattan, Kansas individually saved 5,783 MMBTUs over all categories. They saved $243,642 in energy by switching 40,413 incandescent lamps to compact fluorescent lamps. That is enough energy to power 331 households for a year (takechargeks.org). "Statewide, 110,214 MMBTUs of gas and electricity were saved, with a total value of $2,341,025. This equates to

19,002 barrels of oil not imported, taking 3,300 cars off the road, or enough energy to power 985 Kansas homes for a year." (Green victory).

Chapter 2 - Residential Energy Audit

The first step to home energy improvement is having a professional auditor perform an energy audit. This will reveal the main areas where the house is losing energy. A qualified auditor can be found by looking on a state's website or by looking in the phonebook for local companies. Additionally, local utility providers may perform audits.

When an audit is performed, the auditor examines all areas of a house and the residence's utility bills from previous years. Evaluating previous utility bills may pinpoint when the most energy is used. If the energy bill is unusually high in the summer compared to the winter, there may be a problem with the cooling equipment. The auditor will evaluate the outside of the house and take measurements inside to determine the size and volume of the home and the number of windows. The auditor will also examine the appliances in the kitchen and the heating and cooling equipment in the basement, attic, and outdoors. The residents of the home are encouraged to advise the auditor if a room is cold, damp, or drafty. Such observations help the auditor focus on that room and determine the cause of the problem. All of the information is amassed to assess how well the home performs. At some point during the audit, the auditor will perform a calibrated blower door test.

Blower Door Test

A blower door test is used to measure the infiltration rate of the house. Infiltration is "the uncontrolled flow of outdoor air into a building through cracks and other unintentional openings" (Principles of HVAC). Air will flow into a house if there is a pressure differential between the inside and outside. Using the principle of a pressure differential, a blower door can measure how much air is infiltrating into a house. As a first step, a trained energy auditor attaches a blower door frame to a door in the house. All other doors and windows in the house must remain closed throughout the test. A fan in the blower door blows air out of the house reducing the pressure inside the house until the pressure differential between the inside of the home and the outside is 50 Pascal. Air is constantly seeking equilibrium, so as the air pressure in the house decreases, air migrates into the house through cracks to equalize the inside and outside pressures. The rate of the air flowing into the house is measured by an air pressure gauge on the blower door when the pressure differential reaches 50 Pascal. This air flow is listed as CFM50, or the rate of air blown by the fan in cubic feet per minute when the pressure differential is 50 Pascal. If the blower door is calibrated, it will determine how tight the overall construction of the house is. The lower the amount of air coming into a home is the better the home's energy efficiency. A blower door cannot determine the exact location of leaks in a home; it can only determine the total air that is leaking. Therefore, to determine where the leaks are occurring, either blower door tests on individual rooms or fog tests can be performed.

A blower door test done for a specific room can better pinpoint where air infiltration is occurring. For example, a blower door test performed on a room with a single window can determine if that window is leaking. The window can then be sealed. The whole house test cannot pinpoint which windows are leaking. Testing each room individually shows more clearly the locations of the leaks. A blower door test for an individual room is also beneficial because it tells the rate of air infiltration from that specific room. Consequently, rooms that show the highest rate of air infiltration can be addressed first.

An even more accurate way to determine the location of air leaks in a house is to perform a fog test. To conduct a fog test the house must be pressurized, but in a different way than when performing a blower door test. A blower door test depressurizes the house through a fan that blows air out of the home to determine the amount of air coming into the home. A fog test does the opposite, blowing air into the home and making the inside more pressurized than the outside. Once the home is pressurized it is filled entirely with fog produced by a simple fog machine. The fog is a non-toxic glycol-based solution, which will not harm the house or the inhabitants (www.greenbuildingadvisor.com). Once the home is filled with fog the pressure inside the home will push the air out through any available opening. Observers standing outside the home can see where the fog is escaping and identify the positions of leaks in the building shell. Common areas for leaks are around windows or under the eaves. However, a fog test cannot determine the rate of air leaving a specific opening.

"The American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) recommends that we have approximately 0.35 air changes per hour (ACH) in our house and buildings in order to maintain healthy indoor air quality" (Energy Audit). Excessive infiltration brings unconditioned air into a space and makes the heating and cooling equipment work harder to heat or cool the air. As the unconditioned air enters a home through cracks, the air that has already been conditioned is pushed out of the house. In essence the exchange results in the Heating Ventilation and Air Conditioning (HVAC) equipment performing twice the work and is highly inefficient. Having too little infiltration is also undesirable. If a house simply re-circulates the same air, the number of allergens and germs in the air stream would continuously grow. Most residential homes, including the President's Residence, do not have HVAC equipment that provides for outside air to be incorporated into the air delivery. Therefore, it is important that the house allow some air to enter through infiltration.

Figure 2.1 Blower Door Test (http://www.energysavers.gov/your_home/)

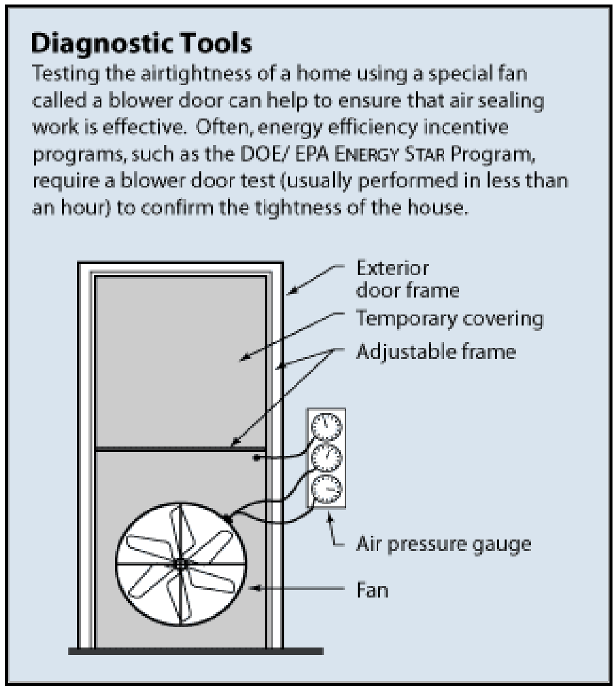


Figure 2.2 Chad Robinson Conducting a Blower Door Test

President's Residence Energy Audit

When the Take Charge Challenge was announced for Kansas State University, Noel Shultz, the first lady of the university and co-chair of the local campaign, was the first to have her home audited. She wanted to set an example for the rest of the community. So in March 2011 Chad Robinson from Building Performance Company visited the President's Residence to complete an energy audit. Mrs. Shultz mentioned that "the home is similar in age to other homes in the area when it comes to energy efficiency. The first step is to find out where we can make improvements to save both energy and money" (sustainability.ksu.edu). Since the home is comparable in age and construction to other homes in the area, the audit could be a good indicator of changes that other homes in the community could make to improve their energy efficiency.

Mr. Robinson first installed a blower door test on the door to the sunroom to measure the house's infiltration rate. He then walked through the residence taking detailed measurements of each area. The measurements were used to determine the volume of the house, which, in turn, was used to calculate the infiltration rate of the residence. He also examined the appliances both in the upstairs kitchen, the downstairs kitchen, and the laundry room on the first floor. The heating and cooling equipment in the basement mechanical room, in the third floor mechanical room, and in the new attic over the garage were inventoried as well.

When performing the blower door test, even without the final calculations, it was evident that the residence had a problem with infiltration. So while completing an inventory of the home's rooms, Mr. Robinson also looked for areas of air leakage. These areas were documented and cited as places that needed improvement in the audit results.

Audit Software

Once the necessary data was collected, Mr. Robinson entered it into a REM/Rate software program. The REM/Rate software program is a home energy rating tool that "calculates heating, cooling, hot water, lighting, and appliance energy loads, consumption and costs for new and existing single and multi-family homes" (http://www.archenergy.com). Mr. Robinson used the information gathered at the President's Residence to show where the home was using the most energy, through the use of graphs and tables. The audit also included a list of improvements to be made to the residence in order of most cost effective to least cost effective. Cost effectiveness is determined by the monetary payback of a project. Simple payback is the "initial investment divided by annual savings" (www.energysavers.gov). The simple payback gives the payback period in total years before the homeowner will see a return on their investment. Smaller items may have a faster payback period because of a small initial investment, but if a large investment has a high predicted return on investment, it could also be listed as one of the most cost effective improvements. The full audit is attached in Appendix A.

Along with the areas to improve, the audit report contains numerous graphs and charts that visually depict the monetary savings a homeowner could realize by making the recommended upgrades. Auditor estimates on the cost of upgrades are factored into the simple payback and total savings calculations. The savings calculations are not accurate for the residence, though, because the home is not of typical residential construction. The graphs, charts, and savings estimates from the software all assume that a home is built using current construction standards. Since the President's Residence was built 88 years ago, the suggested upgrades are either not applicable or more costly than stated in the report.

The scope of the upgrades was determined using the Efficiency Kansas Material and Installation Manual (EKMIM), but the estimated cost was generated by the REM/Rate software.

The actual cost of the updates may vary “tremendously,” according to the audit, based on the residence’s location and the availability and expertise of contractors in the area. Owners must carefully examine these numbers before applying for loans or deciding which projects to undertake. Contractors are encouraged to examine the EKMIM when offering bids on the project to fully gauge the actions involved in the upgrade process.

Mr. Robinson made clear, however, that the purpose of some items in the audit report was to act as an example for other homeowners in the area. While the President's Residence might not recognize the savings from a certain upgrade, other residences might benefit from that same upgrade. Therefore, in the spirit of using the President's Residence as an example for the community, all upgrades were considered. It is important to review the audit report, determine which upgrades are applicable, and determine the estimated paybacks with consideration that the software is designed for a contemporary home. The Author's intent in this paper is to compare the calculations of the audit report with personal calculations that reflect the age and construction of the home.

Restrictions of the Audit

The full audit report contained many suggestions for improving the energy efficiency of the President’s Residence. However, the audit did not take into account all aspects of the residence, so that certain recommendations were not practicable. At one point in the audit when referring to wall insulation Mr. Robinson stated that “the ‘insulation’ is somewhat theoretical for purposes of this report. The intent is to show what the savings would be if the walls were insulated. Although we understand that implementing this suggestion would be quite difficult and more costly than stated, a house that could easily be retrofitted to insulate the walls would realize this savings” (Audit, Cost Effective Energy Table). In essence, while the energy audit performed by Mr. Robinson showed where specific improvements could be made to the President's Residence, the audit could also be used more generally as an example for others considering a retrofit of their homes.

In addition to various recommendations that might not be practicable for the President's Residence, the audit relies on particular inputs and factors contained within the REM/Rate software that might not completely conform to the specifications of the President’s Residence. The software requires the auditor to ‘build’ the house online using standard construction options.

The auditor inputs the house's location, construction details, insulation details, window details, and the type of heating and cooling system. Using these inputs, the program assesses where energy is lost and identifies solutions to improve the situation.

Problems first arise when inputting data regarding the house. Many of the President's Residence features are not listed in the software libraries. For example, the heating and cooling system in the President's Residence is air handling units (AHUs) as shown in Figure 2.3 and a split system air conditioning unit as shown in Figure 2.4. There are two AHUs in the home: one serves the basement and the first floor while the other serves the second and third floors. Because there was not space available for ductwork to be routed throughout the home from one unit, two AHUs were installed. Steam from the power plant on campus is provided to the President's Residence where it is sent to a heat exchanger. The heat exchanger uses the heat from the steam to heat the water in the hot water coil in the air handling unit. Chilled water is provided to the AHU's chilled water coil for air conditioning. The 1998 garage addition discussed in Chapter 3 is served by the split system air conditioning unit. The audit software does not have an option for an AHU; the only choice is a gas-fired furnace. Also, the window choices in the software program do not include the historic windows that are used throughout most of the President's Residence. Even though the original windows in the residence are single pane with an exterior storm window, their insulating properties are not the same as the single pane window referenced in the software. More testing would be needed to determine an equivalent in the REM/Rate software.

Figure 2.3 Attic AHU

Figure 2.4 Outdoor Condensing Unit

Aside from the problems inputting data, there are also issues with some recommendations generated by the software. As stated by Mr. Robinson when discussing wall insulation, not all the suggestions for improvements are compatible with the construction of the President's Residence. The software suggests improvements based on assumed construction specifications, which do not always coincide with the actual construction of the President's Residence. The

President's Residence was built in 1923 and originally did not include mechanical heating or cooling equipment. The house was constructed with walls of thick stone to keep the house cool in the summer and fireplaces in the main rooms to heat the house in the winter. The stone walls were covered with plaster on the inside and have no insulation. When the wall construction was input into the software the immediate response was to add insulation to an un-insulated wall, which makes sense for a current home but not a historic home. Adding insulation to the walls without consideration of the historic construction methods and materials might cause more harm than good. Fully interpreting the energy audit results and ascertaining how they can be applied to the President's Residence requires a full understanding of the residence, to include construction materials, construction methods, and system functionality. This understanding of a house is necessary before decisions about upgrades can be made.

Chapter 3 - President's Residence History

Beginning in 1923, the presidents chosen to serve the Kansas State University community had a permanent home on the campus. Located at 100 Wilson Court, the three-story, limestone dwelling was built to blend with the surrounding campus buildings while acting as a private residence for the University's first family. Funding for the construction of the house came from Mrs. Mehitable C.C. Wilson in honor of her late husband, David Wilson, one of Manhattan's original founders.

Before the house was built, the presidents lived off campus in a number of different places. When President Dennison was in office and before the campus was situated in its current location, he lived on Hylton Heights Road. President Anderson lived in Junction City but moved into Preston House when the campus moved to its present location (see Figures 3.1 and 3.2). Preston House was built by the widow of Professor Preston in 1866. President Anderson and President Fairchild lived here until President Fairchild constructed an actual residence for the president of the University. After President Fairchild moved into the new house in 1885, Preston house was used for other purposes on campus. In 1920 it was turned into the college hospital. It had a barracks attached to it in World War II. It was later used for storage and subsequently demolished to construct Lafene Student Health Center.

Figure 3.1 President's Residence 1875-1885 (Willard)

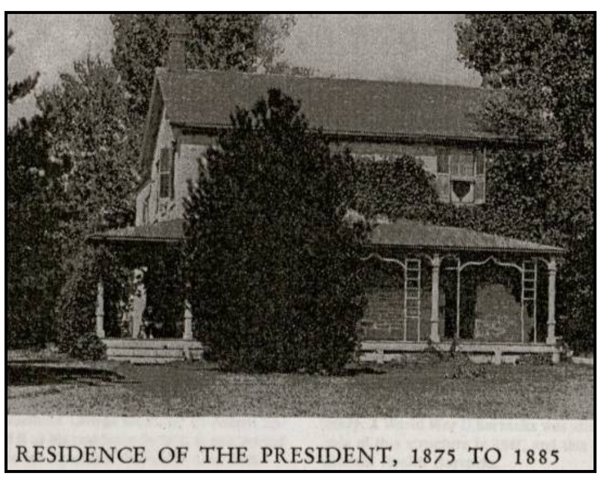
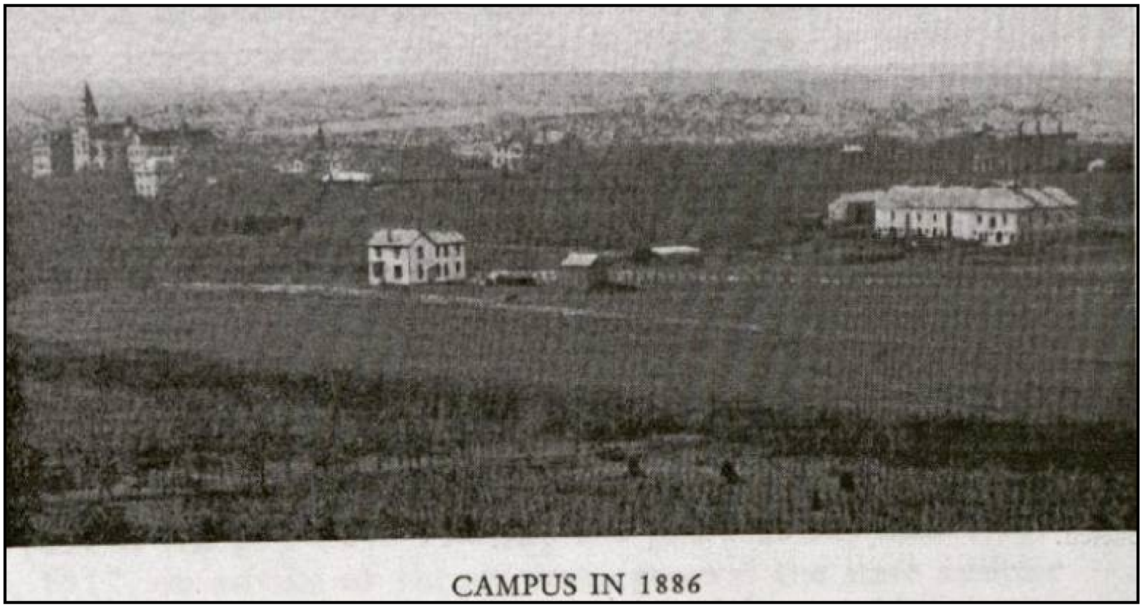


Figure 3.2 Preston House Rendering (Willard)

President Fairchild lived in the newly built President's Residence (see Figures 3.3 and 3.4), from 1885 until 1895. Unfortunately, in 1895 the house was struck by lighting and burnt to the ground. Following the destruction of the house, University Presidents Will, Nichols, and Waters all lived in houses of their choosing. President Waters built his own house, which was subsequently purchased by Kappa Kappa Gamma for their sorority house after his term ended.

Figure 3.3 President's Residence 1885-1895 (Willard)

Figure 3.4 Campus in 1886 (Willard)



100 Wilson Court

Figure 3.5 100 Wilson Court September 2011

President Jardine was next in office. He lived on Houston Street for the beginning of his term but had construction started on 100 Wilson Court using funds left to the college by Margret Wilson, widow of David Wilson and a friend of the college. The new residence was built among trees where the former arboretum was once situated. 100 Wilson Court has housed seven University presidents since its completion in 1923. It has also changed over time to stay current in its utilities and amenities. Air handling units and a split system air conditioning unit serve the home and keep it cool in the summer and warm in the winter. The appliances in the kitchen areas have been updated and the lighting is primarily compact fluorescent. The original floor plans from 1923 are shown in Figures 3.6, 3.7, 3.8, and 3.9.

Figure 3.6 Basement Floor Plan

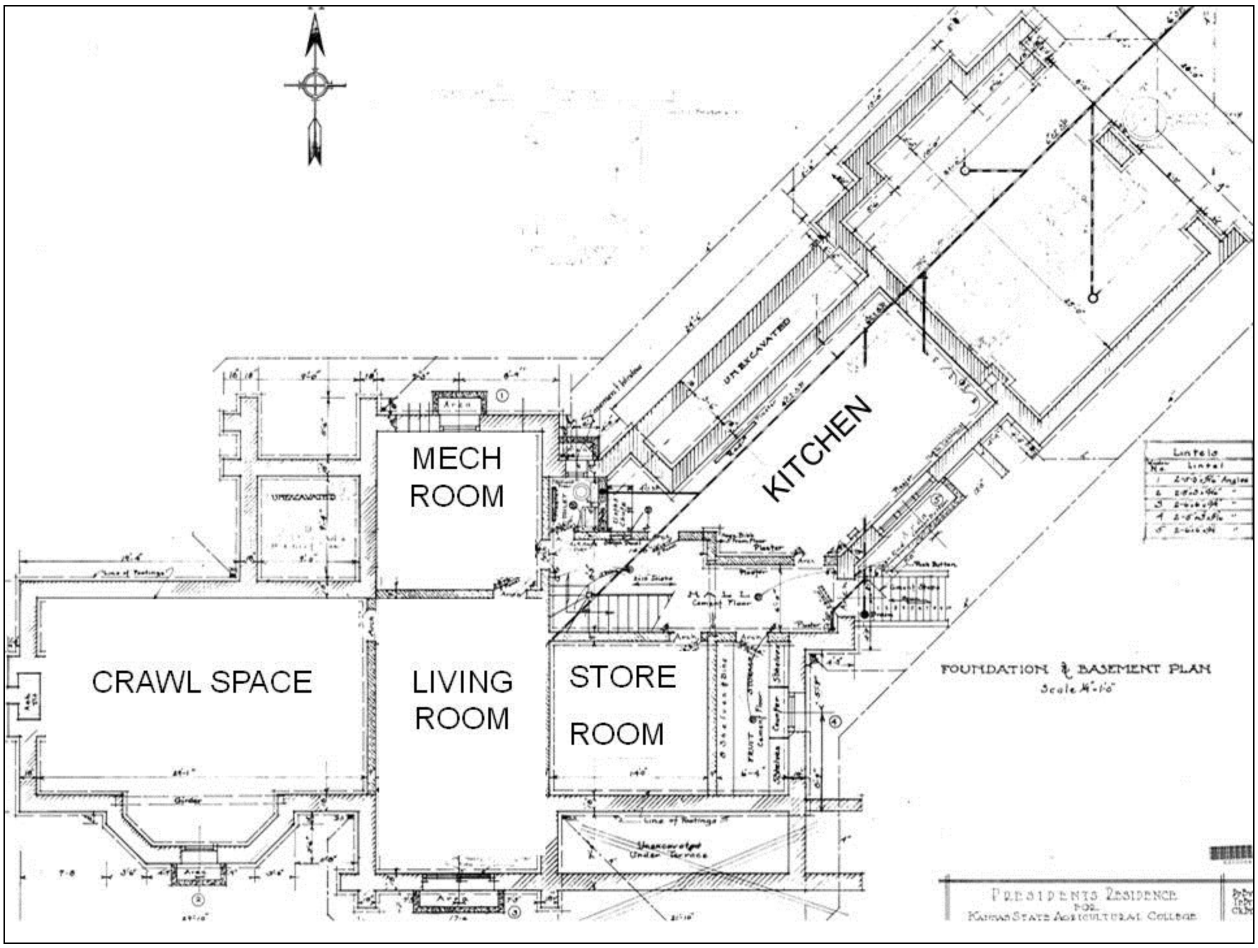


Figure 3.7 First Floor Plan

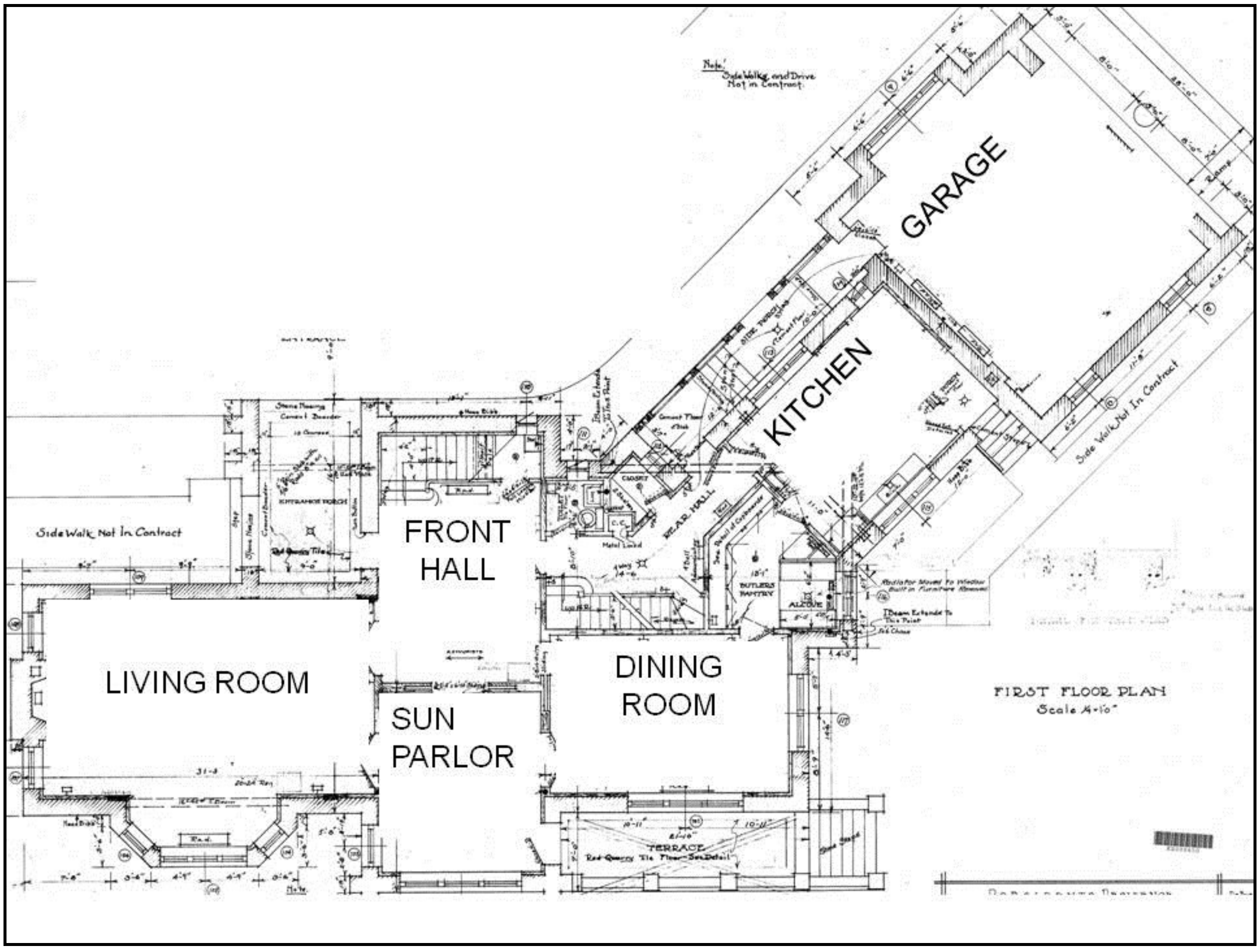


Figure 3.8 Second Floor Plan

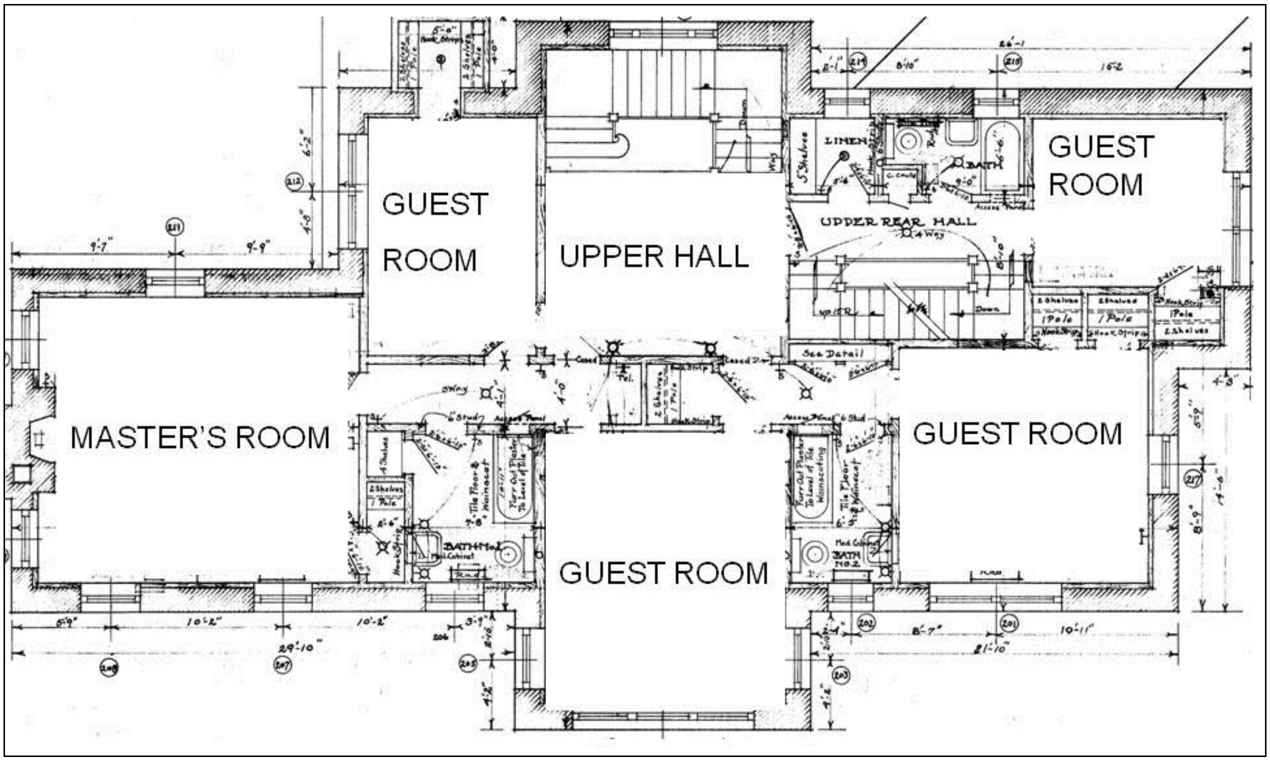
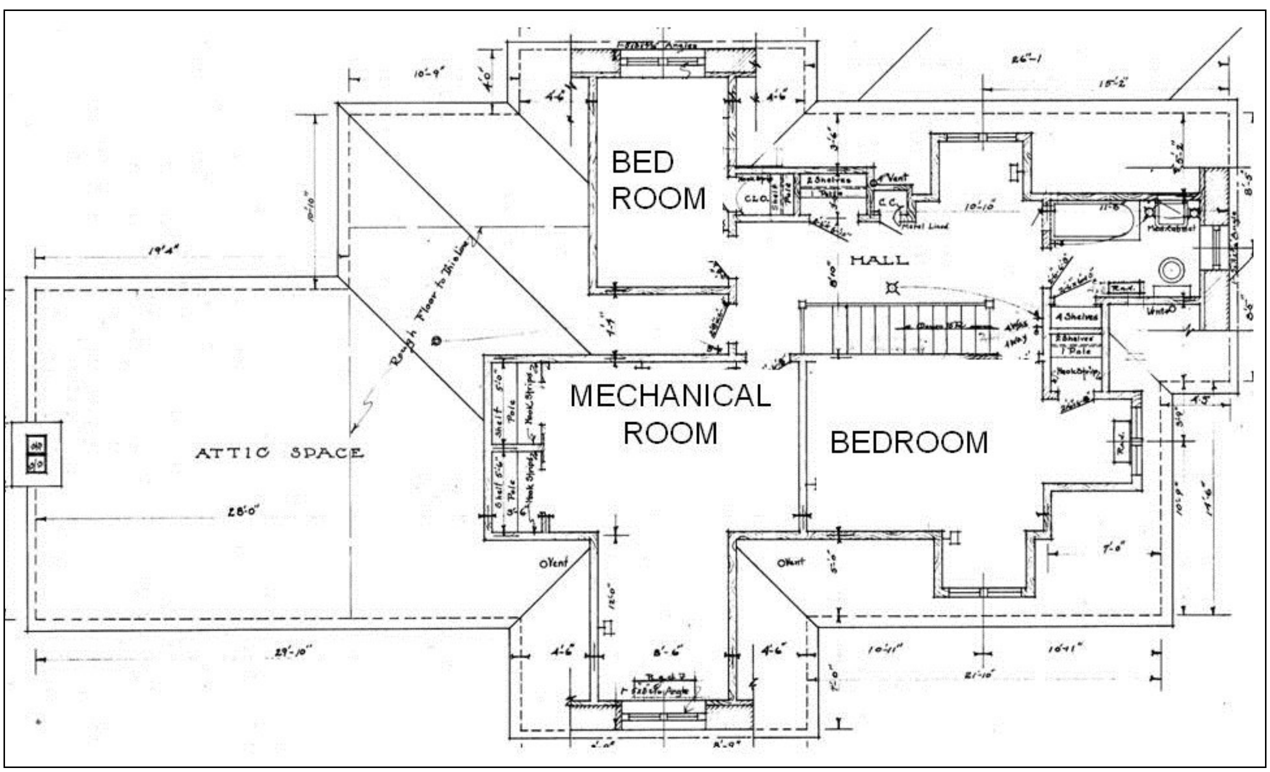


Figure 3.9 Third Floor Plan



The cost of the original structure was $31,000. Additions and renovations have been done to the property since that time. The most recent addition was a garage built during the Wefald tenure in 1998 that included the repurposing of the old garage into a living room shown in Figure 3.10 and Figure 3.11. Currently, the home has seven bedrooms, four full bathrooms, two half bathrooms, a front living room, a sunken living room, a dining room, a sun parlor, an enclosed terrace, two mechanical rooms, an eat-in kitchen on the ground level, a finished basement, a second kitchen in the basement, and a two car garage. The mechanical rooms in the basement and in the third floor attic both contain a Trane M-Series air handling unit. Steam is delivered to these two units from the campus power plant for heating and chilled water is used for air conditioning. The attic in the new garage addition houses a split system air conditioner with the condensing unit behind the garage.

Figure 3.10 1998 First Floor Living Room Addition

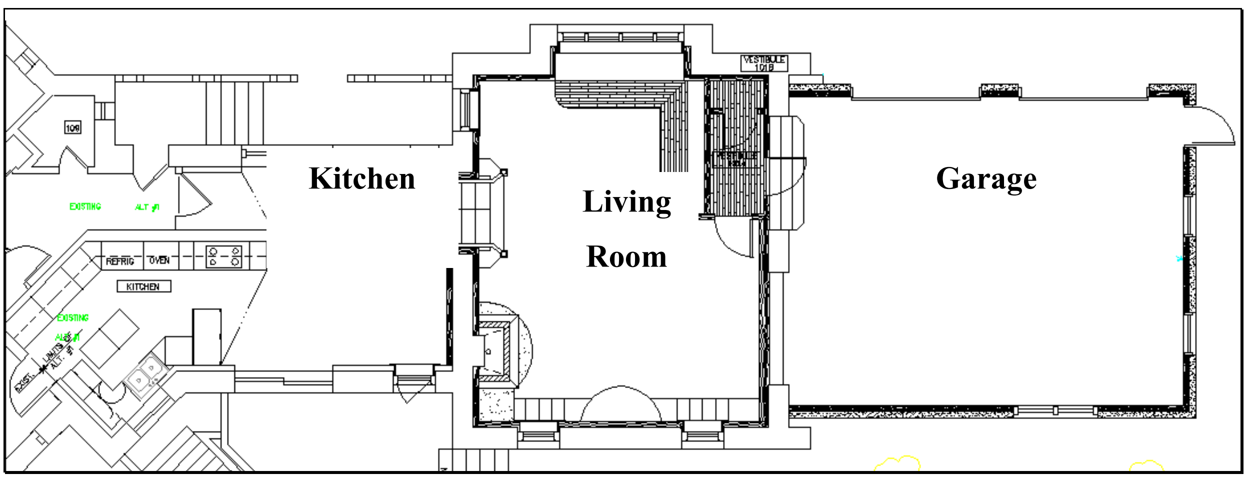
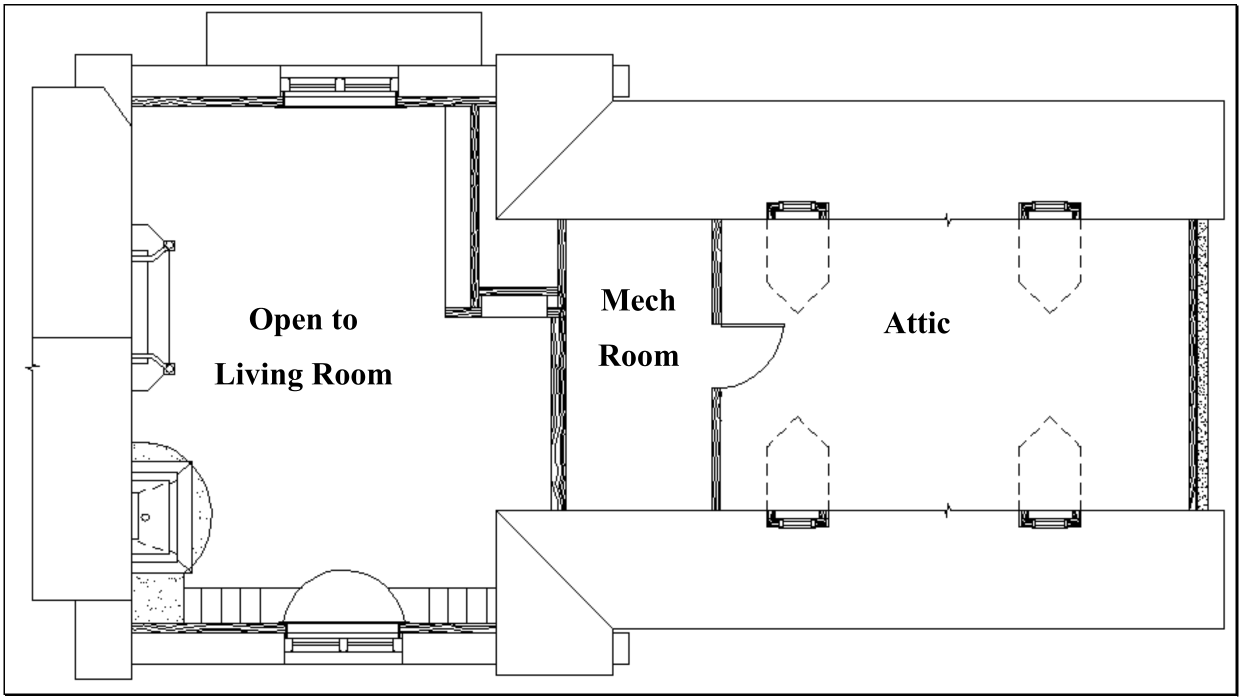


Figure 3.11. 1998 Second Floor Living Room Addition



Historic Property

The President's Residence was built in 1923, which makes the house 88 years old. When starting any major renovation project, the age of the home should be taken into account with consideration of the features that make the house unique. Unsympathetic renovation could permanently damage or destroy those features. A building over 50 years of age can also be considered for listing in the National Register of Historic Places if it meets certain criteria of being historically, architecturally, and culturally significant to the country.

"The way a property gets listed in the National Register of Historic Places is that the forms and documentation go to the State Historic Preservation Office (SHPO) of the state where the property is located. The SHPO can take one of several options: reject the property, ask for more information, list the property just with the state, or send the forms to the National Register for listing in the National Register of Historic Places. Once the National Register receives the forms, they conduct a similar review process" (www.nps.gov). The goal of both the state and the federal government is to ensure that the architectural, archeological, and cultural history of the country is preserved as a living part of our community life. Buildings significant to time periods, architectural styles, and people or places represent an irreplaceable heritage and should be protected for future generations.

The President's Residence is architecturally significant in that it reflects the style of other Kansas State University academic buildings and uses Kansas limestone. It is culturally significant in that many influential people have lived in and visited the house. Buildings can become historically significant by having an historically significant person reside in them, such as a former President of the United States. In such situations, it would be important to maintain the same layout of the home and document in which room they stayed. The President's Residence is also culturally important to the Kansas State University as a critical component of the larger campus.

The President's Residence is not currently listed in the National Register of Historic Places. However, the home may be eligible for listing. Given the historical significance of the house, there are a number of issues to consider when renovating to preserve the historic character of the home. The Secretary of the Interior's Standards for Rehabilitation provide guidance. Major renovations should keep as close to the original floor plan as possible by avoiding subdividing spaces and interrupting flow. The installation of drop ceilings should be avoided where they would cover intricate moldings on the ceiling or partially cover tall windows. Stairs should be kept in their original locations. Interior features such as crown moldings, cornices, and fireplace mantels should be retained. Refurbishing is allowed if necessary, but mechanical, electrical, and plumbing features original to the house such as radiators, plumbing hardware, and light fixtures should be retained. Lastly, caution should be used when considering insulation of original masonry walls (Preservation Brief 18). Keeping these principles in mind will help preserve the historic character of the President's Residence while leaving room for updates to make the house more energy efficient and comfortable.

Chapter 4 - Energy Audit Results

Once the data from the audit was entered into the REM/Rate software program and the results generated, Mr. Robinson presented a final audit, which is attached as Appendix A. The audit included graphs of potential energy savings that could be achieved once changes were made to the residence from a list of suggested improvements. As discussed previously, the energy savings are estimates but the graphs do show which updates have the potential to save the most energy if implemented. The primary focus of the suggested improvements was to combat air leakage. Based on the results of the audit and its recommendations, student and faculty volunteers from the Kansas State University Architectural Engineering and Construction Science Department completed a service project to address some of the issues.

Programmable Thermostats

The first item on the list of upgrades contained in the audit is the installation of programmable thermostats. The new garage addition has a programmable thermostat, but the original section of the house does not. Programmable thermostats allow the house to be conditioned for different occupancies at different times of the day. The installation of a programmable thermostat allows temperatures to be adjusted to reduce the need for heating or cooling during non-peak hours, avoids the need to manually change the temperature, and avoids the risk of forgetting to change the thermostat to desired temperatures. The thermostat placement was also cited as a problem by Mrs. Shultz. She said that the placement of a thermostat in the upper hallway did not allow for an accurate reflection of the temperature conditions in the other rooms. The discrepancies between the set temperature and the actual temperatures throughout the affected rooms indicated that the thermostat should be moved to a different location.

Figure 4.1 Upper Landing Existing Thermostats

Air Leakage

Air leakage in a home can occur in many different places. Often, air leaks into a house through seams between building materials and holes, such as exhaust vents in the attic. Generally, sealing these cracks takes minimal effort and helps save energy, increase the comfort of the occupants, and avoid allowing moisture into the home.

The second item on the upgrade list was to reduce the air leakage in the residence by 65% to 5,000 CFM50 or 5,000 cubic feet per minute (CFM) at 50 Pascal (Pa). This means that to create a pressure differential of 50 Pascal between the home and the outside, the fan in the blower door frame would have to be blowing air at a rate of 5,000 CFM. A 50 Pascal pressure difference is much higher than normal pressure and would never occur naturally. The reason to use such a high pressure differential is to make the test repeatable. In this way the results are not subject to changes in differing weather conditions or other climatic and geographic changes seen in different areas of the country. This also allows the same blower door test to be performed across the entire country no matter the home's location. "CFM50 is the airflow from the blower door fan needed to create a change in building pressure of 50 Pascal. A 50 Pascal pressure is roughly equivalent to the pressure generated by a 20mph wind blowing from all directions. CFM50 is the most commonly used measure of building air tightness and gives a quick indication of the total air leakage in the building envelope" (www.energyconservatory.com). Using the equation in Figure 4.2 and the information provided in the President's Residence energy audit, it can be determined that the CFM50 rate currently is 14,285 CFM50. This indicates an extremely leaky house.

Figure 4.2 Percent Reduction in CFM50 (www.energyconservatory.com)

$$\% \text{ Reduction} = \frac{\text{CFM50 (before)} - \text{CFM50 (after)}}{\text{CFM50 (before)}} \times 100$$

Using the CFM50 number the air changes per hour (ACH50) can be determined. ACH50 is the number of air changes per hour that occur at a pressure differential of 50 Pascal between the house and the exterior. ACH describes how many times the total volume of air inside the home is replaced every hour. The first step in calculating a home's ACH50 is to multiply the CFM50 by 60 minutes per hour. The second step is to divide that number by the volume of the home in cubic feet. This equation is shown in Figure 4.3. From this number the home's natural ventilation rate can be estimated in ACH.

Figure 4.3 ACH50 Equation

$$\text{ACH50} = \frac{\text{CFM50} \times 60 \text{ Min/hr}}{\text{Volume (ft}^3\text{)}}$$

CFM50 = cubic feet per minute (ft^3/min) at 50 Pa

ACH50 = air changes per hour at 50 Pa

A blower door test creates an artificial pressure difference between the home's interior and exterior. Essentially, a blower door test takes the air that was naturally infiltrating the home and amplifies it. The ACH50 is not the ventilation that occurs when the blower door test is not running. To determine the rate of infiltration when a blower door test is not being performed, the location of the home, the height of the home, and the degree that the home is sheltered from the wind must be taken into account. Lawrence Berkley Laboratory at the University of California has combined all of these factors into a LBL factor. A table based on the area code of a home is available to find the LBL factor for a home (www.energystar.gov). The natural ventilation of a home in ACH is found by dividing the ACH50 by the LBL factor, as shown in Figure 4.4.

Figure 4.4 ACHnat Equation

$$ACH_{nat} = \frac{ACH_{50}}{LBL\ Factor}$$

The estimated natural ventilation rate from the energy audit in air changes per hour (ACH) was 1.17, as shown in Figure 4.5. Mr. Robinson arrived at this number using the calculated CFM50 and multipliers obtained from ASHRAE standards to account for wind, building location, and building height. 1.17 ACH indicates a high leakage and a building of loose construction. The natural ventilation is only an estimate and can vary by region. A blower door test cannot directly indicate the infiltration rate of the home. Based on the equation in Figure 4.6 from the Principles of HVAC book, the volume of 64,342 ft^3, and an infiltration rate of 1.17 ACH from the energy audit, the infiltration rate would be 1,255CFM. Using Figure 4.6, assuming loose construction, and assuming a design temperature of 0°F, the infiltration rate would be 1,395CFM.

Figure 4.5 Energy Audit Natural Ventilation

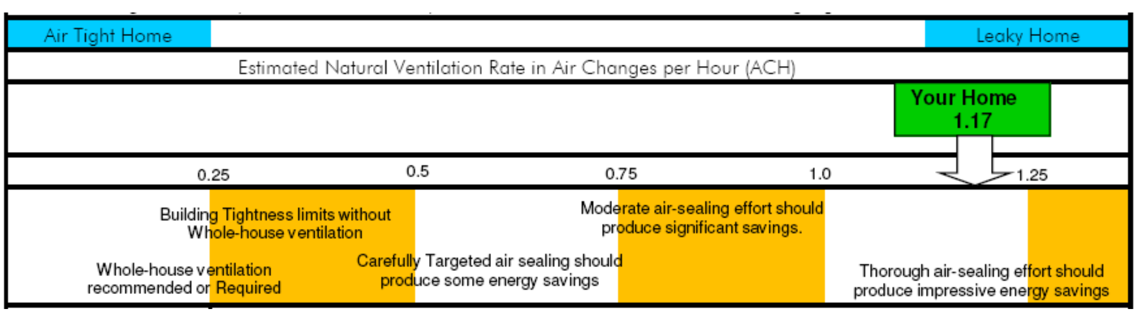


Figure 4.6 Infiltration Rate (Principles of HVAC, 2005)

$$Q = ACH \times VOL/60$$

Q = infiltration rate, cfm

VOL = gross space volume, ft^3

Table 4.1 Air Changes per Hour Based on Airtightness (Principles of HVAC, 2005)

ACH										
	Outdoor Design Temperature, °F									
Class	**50**	**40**	**30**	**20**	**10**	**0**	**-10**	**-20**	**-30**	**-40**
Tight	0.41	0.43	0.45	0.47	0.49	0.51	0.53	0.55	0.57	0.59
Medium	0.69	0.73	0.77	0.81	0.85	0.89	0.93	0.97	1	1.05
Loose	1.11	1.15	1.2	1.23	1.27	1.3	1.35	1.4	1.43	1.47

As stated previously, some amount of natural ventilation is beneficial for a space. With no natural ventilation the occupants of a building could be sickened as germs and pathogens from sneezing, coughing, and other occurrences get re-circulated throughout the home. However, while some outside air should be introduced into living spaces, the President's Residence introduces too much air into the house. The house has sufficient natural ventilation to preclude the house from re-circulating stale air but unconditioned air from the outside is making its way inside and putting an extra load on the heating and cooling equipment.

The goal of the audit is to reduce air leakage and infiltration by 65% and make the house comparable to a house with tight construction. A 65% reduction goal for the blower door test is 5,000 CFM50. It is unclear how this percent reduction would affect the natural ventilation since the calculations are not related, but a 65% reduction in the natural ventilation rate would decrease the infiltration to 0.76 ACH.

How to Fix the Infiltration

To deal with the large problem of infiltration, Mr. Robinson went through the house and detailed ten areas of concern. The first area was in the attic above the second floor. The picture in Figure 4.7 shows a gap between the outside stone and the inside plaster wall in which air is moving into the home. When insulating the attic during the service project, this gap was sealed.

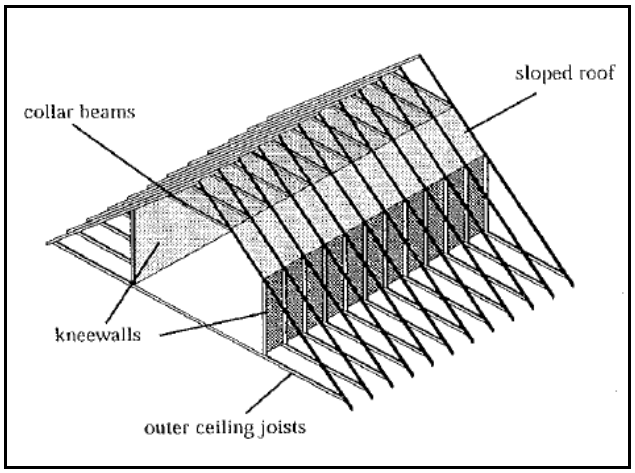
Figure 4.7 Exterior Wall Air Leakage (Energy Audit)

The next area of concern was the furnace room walls and ceiling. The furnace room is located in what was originally attic space. Installing air handling units in the basement to serve the upstairs would have been impossible given that there was no practical way to run the ductwork through the home. Therefore, a portion of the attic was finished and now houses an air handling unit, not a furnace as assumed in the audit report. Figure 4.8 depicts an area of air infiltration. During the service project, the accessible areas around the attic mechanical room were insulated.

Figure 4.8 Third Floor Mechanical Room Air Leakage

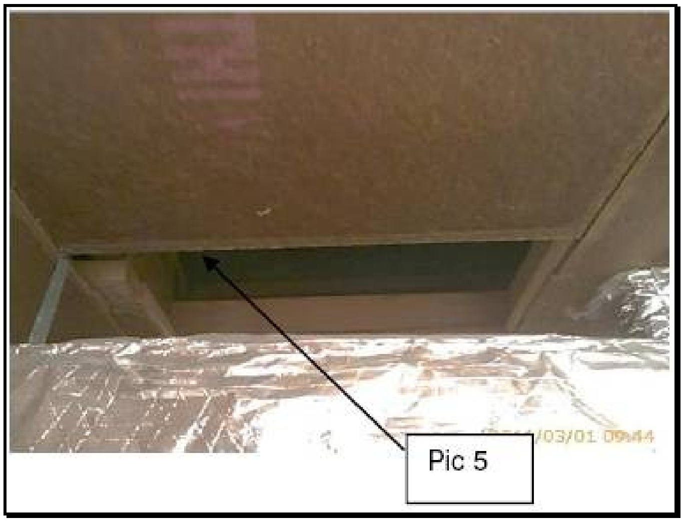
The third area of concern dealt with the kneewall spaces outside the third floor walls. A kneewall space describes an area in an attic where the ceiling is sloped and the walls are only three to four feet tall, as shown in Figure 4.9 Kneewall spaces in the President's Residence are adjacent to the mechanical room in the attic. From the triangular area outside the mechanical room, unconditioned air entered the home. Blocking the air was achieved by installing insulation in accessible areas during the service project.

Figure 4.9 Attic Space with Kneewall (EKMIM)



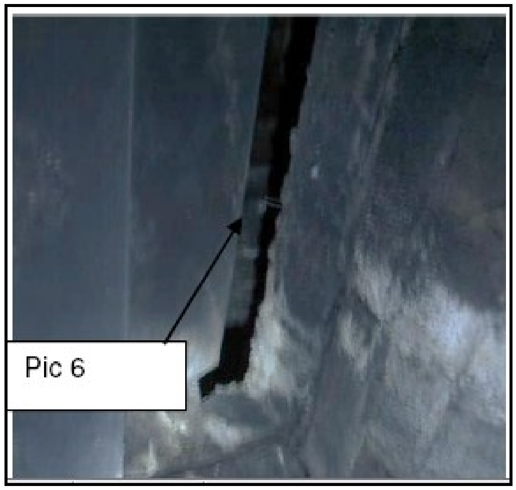
Next on the list of areas of concern were the access doors to the kneewall spaces. Again, unconditioned air from the kneewall space came into the house through cracks around the access doors. Additionally, an access door was missing completely, as shown in Figure 4.10. During the service project, the missing door was insulated and re-installed to cover the opening and the one accessible kneewall space was insulated.

Figure 4.10 Missing Door to Kneewall Space



The chimney damper was the next area of concern. It was old and was stuck open, as shown in Figure 4.11. The damper could not be closed completely even when the service volunteers attempted to close it. The chimney provides needed venting for the gas fireplace. When the home was originally built the fireplaces were wood burning fireplaces located in the master bedroom and the formal living room on the west side of the home. They have since been converted to gas fireplaces. Fireplaces require a flue so that gases can vent to the outdoors. With the chimney damper stuck open, there is always a vent for the fireplace. However, a damper should be able to open when the fireplace is in use and close when the fireplace is inactive. Otherwise, air will readily leak out of the house through the chimney. Repairing the flue and damper will require a professional.

Figure 4.11 Open Chimney Damper



The next area of air leakage on the audit list was around the doors. The weather stripping was old and brittle and in some cases was missing, as shown in Figure 4.12. Instead of expanding to fill gaps when the doors are shut, the old stripping remained contracted and allowed air to infiltrate. Figure 4.13 is a thermal image taken in April 2011 in which the darkest color indicates the location of the warmest air. It is obvious from the image that warm air from inside the house is escaping from around the front door. During the service project, new weather stripping was added to the front door and the door to the kitchen. Figure 4.15 shows the new thermal image of the front door taken after the new weather stripping was installed and Figure 4.14 shows the installation process. The thermal image shows a great reduction in the amount of heat escaping around the door.

Figure 4.12 Old Weather Stripping

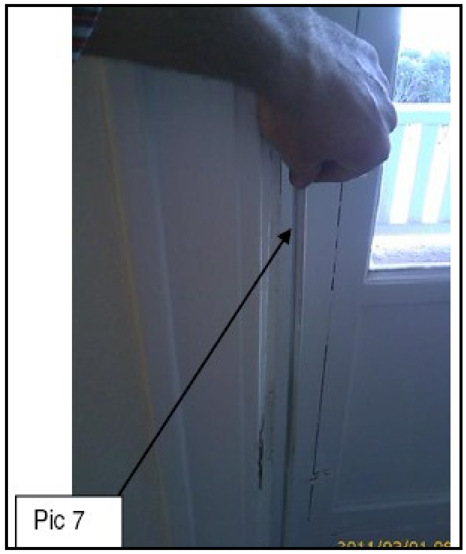


Figure 4.13 Front Door Thermal Image with Old Weather Stripping

Figure 4.14 Installing New Weather Stripping

Figure 4.15 Front Door Thermal Image with New Weather Stripping

In the new garage addition completed in 1998, there was a gap where the wall meets the floor in the attic over the garage, as shown in Figure 4.16. Air was also observed to be entering the new living room through a crack above the bookshelf and around the can lights shown in Figure 4.17. The gap in the attic was sealed during the service project along with the crack above the bookshelf, as shown in Figure 4.18. However, it was not necessary to insulate the can lights, due to the sealing of the gap in the attic.

Figure 4.16 Gap in New Garage Attic

Figure 4.17 Can Lights in New Living Room

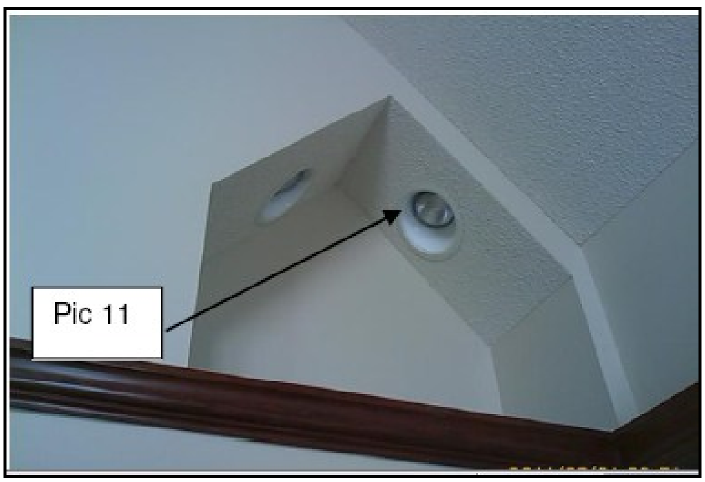


Figure 4.18 Sealing the Crack Above Bookshelf

The next corrective item on the list was to insulate and seal the rim joists and crawl space. The issue was taken care of during the service project. The final item on the air infiltration list was to seal an open conduit in the basement wall, as shown in Figure 4.19. The steel conduit penetrated the basement wall and formerly carried wires into the house. Because the conduit no longer holds any electrical wiring, it is safe to seal the conduit and stop the air leakage or to remove the conduit and repair the wall. The conduit item was not addressed during the service project.

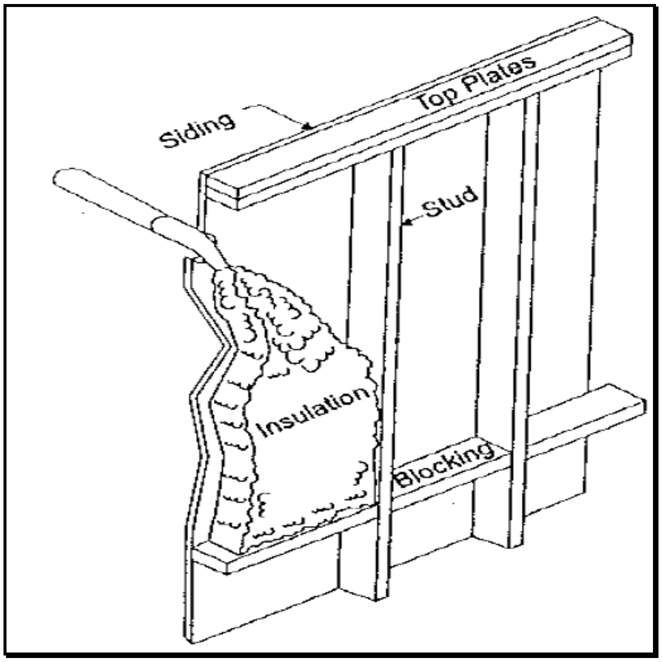
Figure 4.19 Open Conduit in Basement

Above Grade Walls

After addressing air leakage in the home, the next most cost effective measure on the list was to insulate the above grade walls. When the audit was run, the exterior walls were entered into the software program as un-insulated. The wall construction consists of 18-inch thick blocks of limestone and 2 inches of furring to attach 2 inches of plaster to the stone. At the time of the construction of the President's Residence, mechanical equipment to cool the home did not exist. The thick walls were used as a means to keep the house cool during the summer months. During the day the stone would absorb heat from the sun, and at night the stone would slowly release the stored heat and cool down. During the day, the stone would keep the home cool as it slowly warmed under the heat of the sun as the day progressed. It was not an ideal situation, but it was one of the only options available and it worked reasonably well keeping the interior of the home noticeably cooler than the exterior. During the winter months the fireplaces were used to heat the home. Knowledge of the wall construction is necessary to assess whether current insulation techniques for frame construction could be applied to the President's Residence.

The audit's suggested upgrade to correct the lack of insulation on the above grade walls is to blow cellulose insulation densely into exterior walls. Insulation is typically blown into walls by removing some of the siding on an exterior, un-insulated wall and inserting a hose into the hole, which blows insulation into the cavity created by the studs in the wall. The process is shown in Figure 4.20.

Figure 4.20 Blown Wall Insulation (EKMIM)



Although this process was given as an example of insulating un-insulated walls in a modern home, it was not appropriate for use on the President's Residence. Among the reasons for avoiding this technique, is that it would be difficult to drill through 18 inches of stone on the exterior of the house. Additionally, drilling through the interior plaster walls would ruin the walls. Both of these methods would harm the historic character of the home. However, the most important reason for not insulating the walls using this method is mold. The reason the thick stone is good for keeping the home cool is the same reason it will not perform well with insulation. If insulation is added between the exterior stone wall and the interior plaster wall, the insulation slows the transfer of the coldness out of the stone. In the winter this could be considered good, but it may actually cause significant problems. The longer the stone stays cold, the longer the process of evaporation takes, which allows the stone to stay damp for an extended period. When a stone is damp for an extensive amount of time, especially in the winter, there is a potential for mold if the moisture is transferred to the insulation. Also, water on the stone can freeze if the temperature drops low enough. Freezing water expands and can cause structural issues (www.preservationnation.org). For these reasons, insulating an exterior masonry wall is a debatable practice and should be performed only when absolutely necessary and with full understanding of its implications for an historic home renovation.

Ceiling

Much of a home's heat escapes through the attic. Hot air rises and naturally flows towards cooler air as it expands. Therefore, an attic with cracks or openings from improper sealing can experience a measurable amount of heat loss as air escapes to the outside. To alleviate the heat loss, insulation can either be added directly on the ceiling directly below the attic, onto the interior of the roof, or in both places. Most homeowners choose to insulate directly on top of the ceiling of the top floor of their home, as this method prevents them from having to use their heating equipment to heat the entire attic space, which is normally an unused space. If the attic is used for storage of temperature sensitive items, it is better to install insulation on the underside of the roof. Insulation on the underside of the roof will keep the attic cooler in the summer and warmer in the winter, protecting any valuable items.

The next item on the audit's list of upgrades was to insulate the ceiling, specifically of the mechanical room on the third floor and the attic space next to the mechanical room. These areas had insulation in some places but it was strewn about the attic and did not fully cover the full area of the roof. Other areas had no insulation, as shown in Figure 4.21. The audit suggested blowing insulation into cavities because the EKMIM says that it provides a more even coverage of insulation. When the volunteers insulated the attic during the service project, they used rolled batt insulation with an R-38 insulating value, the same R-value suggested in the audit. An R-value is a material's resistance to heat flow (www.energysavers.gov). The higher the R-value, the less heat will flow through it, and the better the insulating quality. Batt insulation was used for various reasons, including that the difference in efficiency between the blown insulation and batt insulation is not significant for the attic in the President's Residence, batt insulation is less labor intensive to install, and batt insulation was donated by the Facilities Department. A portion of the finished, insulated space is shown in Figure 4.22.

Figure 4.21 Un-Insulated Ceiling

Figure 4.22 Insulated Ceiling

Before and after the service project, the author visited the President's Residence and took thermal images of the roof covering the attic. The Department of Architectural Engineering and Construction Science has a FLIR ThermaCAM™ B1 Thermal Imaging Camera donated to the department by Johnston Burkholder Associates. The author used the camera to examine the potential sources of energy loss for the President's Residence. Using a gradient color scale, the camera captures colored images depicting which objects in the photo are hot and which are cool. The images were taken from the outside, so that the warm areas of the photos are areas where heat is escaping from the residence.

The back of the residence provides an unimpeded view of the roof over the attic on the third floor. Figure 4.23 shows the area in a typical picture. Figure 4.24 show the same portion of the home, but the image is a thermal image. The gradient scale on the right of the image shows that white is the warmest area of the image and black is the coldest. Figure 4.24 clearly indicates heat loss through the roof in the attic. Figure 4.25 is another thermal image of the same area, but the thermal image was taken by the author after the attic had been insulated during the service project. There is a marked difference between the heat loss shown in Figure 4.24 and the heat loss shown in Figure 4.25. Figure 4.25 shows the roof as a green-blue color, which means it is a cooler temperature than in Figure 4.24 which shows the roof as red and white. The cooler temperature indicates that less heat is escaping through the attic due to the added insulation.

Figure 4.23 President's Residence Exterior

Figure 4.24 President's Residence Thermal Image Before Insulation

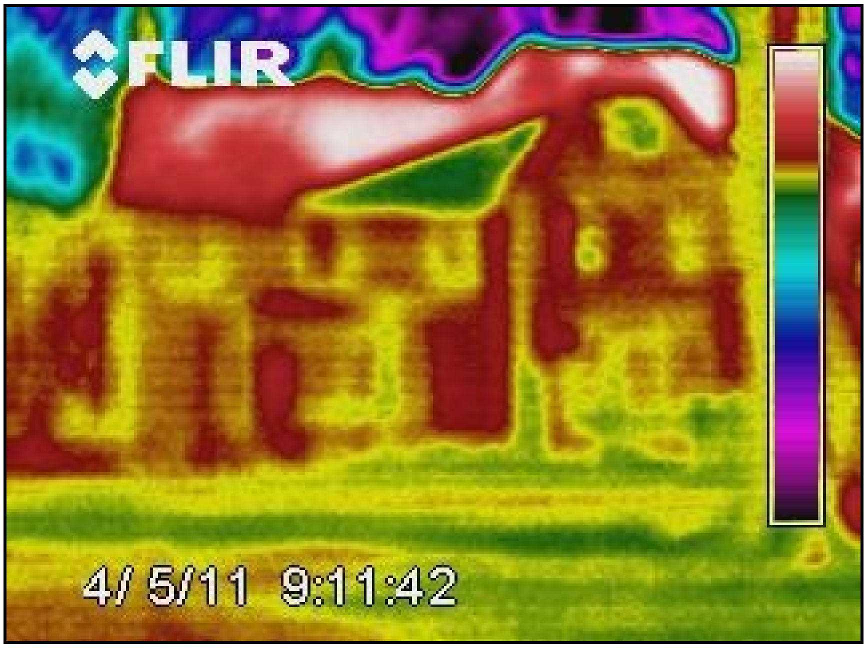


Figure 4.25 President's Residence Thermal Image After Insulation

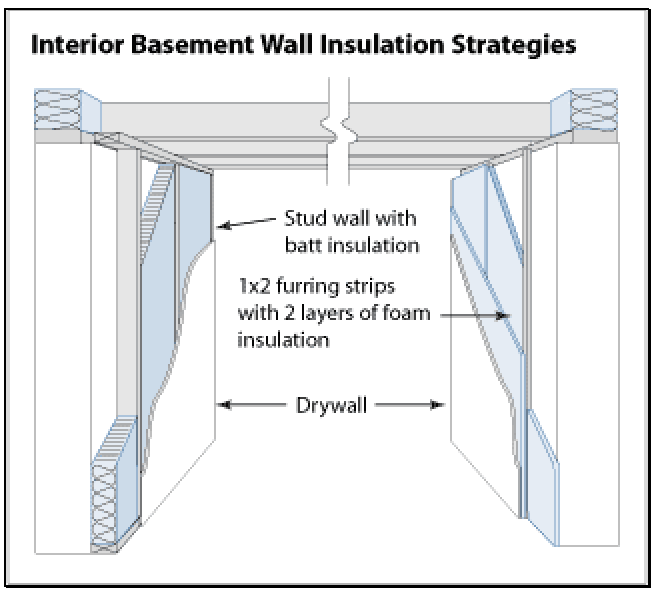
Above Grade Kneewalls

On the third floor next to the attic and mechanical room, the audit suggests installing insulation in both accessible and non accessible kneewall areas. Insulation of kneewall areas was discussed previously in the air infiltration section. The accessible areas were insulated during the service project, but the volunteers decided against cutting into the walls to reach the inaccessible kneewalls.

Basement Walls

For a modern home, a traditional basement space is made of poured concrete for the walls and floor. To insulate the walls, 2x4 stud framing is typically attached to the outer wall and batt insulation is installed between the studs. Drywall is then installed, covering the insulation and the studs. For historic homes, the insulation process is different, given that many historic homes feature brick or masonry walls, which are difficult to insulate with batt insulation because of moisture retention in the insulation. Rather than use batt insulation, a layer of rigid foam insulation is laid against the brick and drywall is attached on top of the foam which is resistant to moisture penetration. Both methods of insulation are shown in Figure 4.26.

Figure 4.26 Basement Insulation (energysavers.gov)



It is important for the insulation to be vapor permeable in a basement, which is often damp. “The ability of a material to retard the diffusion of water vapor is measured by units known as "perms" or permeability. A perm at 73.4°F (23°C) is a measure of the number of grains of water vapor passing through a square foot of material per hour at a differential vapor pressure equal to one inch of mercury (1" W.C.) Any material with a perm rating of less than 1.0 is considered a vapor retarder” (www.energysavers.gov).

Basement walls in historic buildings do not have the same preservation restrictions placed on them as exterior and finished interior spaces. In many cases, a basement was used for storage and its appearance has no bearing on the historical integrity of the home. Therefore, it is acceptable to upgrade a basement to be as energy efficient as possible without impacting the historic character of the home.

The basement walls of the President's Residence are comprised of masonry. However, rather than limestone, as was used for the above grade walls, these walls are constructed of brick. The exterior basement walls in the living room, bathroom, and kitchen are finished, while the walls in the storage area and mechanical room are exposed brick. Since these exposed walls are in service areas, are of a limited size, do not significantly impact the energy efficiency of the house, and are not areas of moisture concern, energy efficiency upgrades were not completed for the walls and upgrade resources and efforts were focused elsewhere.

Crawl Space

A crawl space is an unconditioned area below the home. It is not considered a room and is generally only a few feet high and sloped. Crawl spaces are used primarily for storage and access to the home's utilities. Although the crawl space is not a living area, it should be properly insulated to guard against heat loss and moisture damage. Like the basement walls mentioned above, a crawl space has no value to the historic character of a home and can be upgraded to address a home's energy needs without impacts to the architectural integrity of the structure.

The 560-square foot crawl space in the President's Residence is situated directly beneath the main living room. The crawl space had no insulation and was unconditioned, as shown in Figure 4.27. Heat expands and naturally flows from a warmer space to a cooler space. The temperature differential between the living room and the crawl space was great enough that heat flowed from the warmer living room into the cooler crawl space. With no insulation, the floor joists below the living room did not prevent the heat transfer.

To address the problem, rigid foam insulation was added to the exterior walls and spray foam insulation was applied between the floor joists during the service project. The finished, insulated crawl space is shown in Figure 4.28. The rigid insulation used for the exterior walls had an R-value of R-10. The insulation was cut to fit around piping and attached to the walls.

The spray foam insulation required the volunteers to don full protective gear including gloves, face mask, and coveralls, also shown in Figure 4.28. The foam was sprayed between the floor joists in a layer about an inch thick. The spray foam insulation had an approximate R-value of R-6.7.

Figure 4.27 Un-Insulated Crawl Space

Figure 4.28 Finished Insulated Crawl Space

Rim Joist

A rim joist is a supporting timber or beam that runs along the perimeter of a room onto which all the other floor joists attach. Because it is installed along the perimeter of a room, the rim joist is the closest joist to the exterior of the home. Insulating a rim joist is often overlooked, but insulating the joist can help prevent the infiltration of cold air into a residence. In the President's Residence the un-insulated rim joist was insulated with spray foam insulation during the service project.

Crawl Space Floor

Many residential crawl spaces have dirt floors. It is suggested that crawl space floors be covered with plastic membranes to prevent moisture from seeping through the ground and impacting the structures. Since crawl spaces are dark, enclosed, and unconditioned spaces, any moisture in a crawl space will not evaporate quickly and can seep into the wood of the floor above potentially causing rot and compromising the structure. Mr. Robinson suggested installing a 6 mil plastic sheet on the floor of the crawl space in the President's Residence. However, when the volunteers were in the crawl space to install the new insulation during the service project they found the dirt floor to be completely dry and chose not to install the plastic sheet.

Chapter 5 - Windows

R-values are used to describe walls and U-factors are used to describe windows. Both measure the insulating value of a product. The R-value measures a material's resistance the heat flow. The U-factor is the reciprocal of the R-value and measures the rate of heat flow through the glass of a window. The higher the R-value and the lower the U-factor the better the insulating value of the window. When insulating a home, both wall insulation and the insulating value of windows should be considered. Essentially, windows are large holes cut into the air barrier. Because glass is a poor insulator, each window has a higher heat loss than a wall. Subsequently, the more windows in a home, the more opportunities for heat loss.

The U-factor of a window may be improved in several ways. Individually, a pane of glass will have a U-value of approximately 1 when the inside and outside air films are taken into account. The 1/4 inch architectural glass will have an R-value of 0.1, the outside air film will have an R-value of 0.17, and the inside air film will have an R-value of 0.68. Adding the R-values together and dividing the sum into one will result in a U-factor of 1.

Adding U-factors is not as straightforward as determining R-values because U-factors are not additive. R-values are additive, meaning that these values can be added to determine a total value. The U-factor is the reciprocal of the totaled R-value, in which 1 is divided by the sum of the R-values to determine the U-factor. Table 5.1 details how each component of the windows at the President's Residence contributes to the R-value. The first pane of glass is the storm window, the air cavity is the space between the storm window and the original window, and the second pane of glass is the original window. The total R-value is divided into 1 and the U-factor is determined.

Table 5.1 R-Value of President's Residence Windows (ASHRAE Principles)

R-Value of Original Windows

Outside Air Film	0.17
Glass Pane	0.1
Air Cavity	0.94
Glass Pane	0.1
Inside Air Film	0.68
R-Value =	1.99
U-Value =	0.50

Using the U-value, it is possible to determine the heat loss through the windows. Heat loss occurs when there is a temperature differential across a material. Heat on one side of a pane of glass will attempt to transfer to the cold side of the glass. The lower the U-value of the window, the lower the rate of heat transfer through a window (Kinney and Elsworth). The equation for heat loss is shown in Figure 5.1. The heat loss is based on the area of the material that the heat is transferring through, the U-value of the material, and the temperature differential between the outside and the inside. A smaller temperature differential will result in a smaller heat loss.

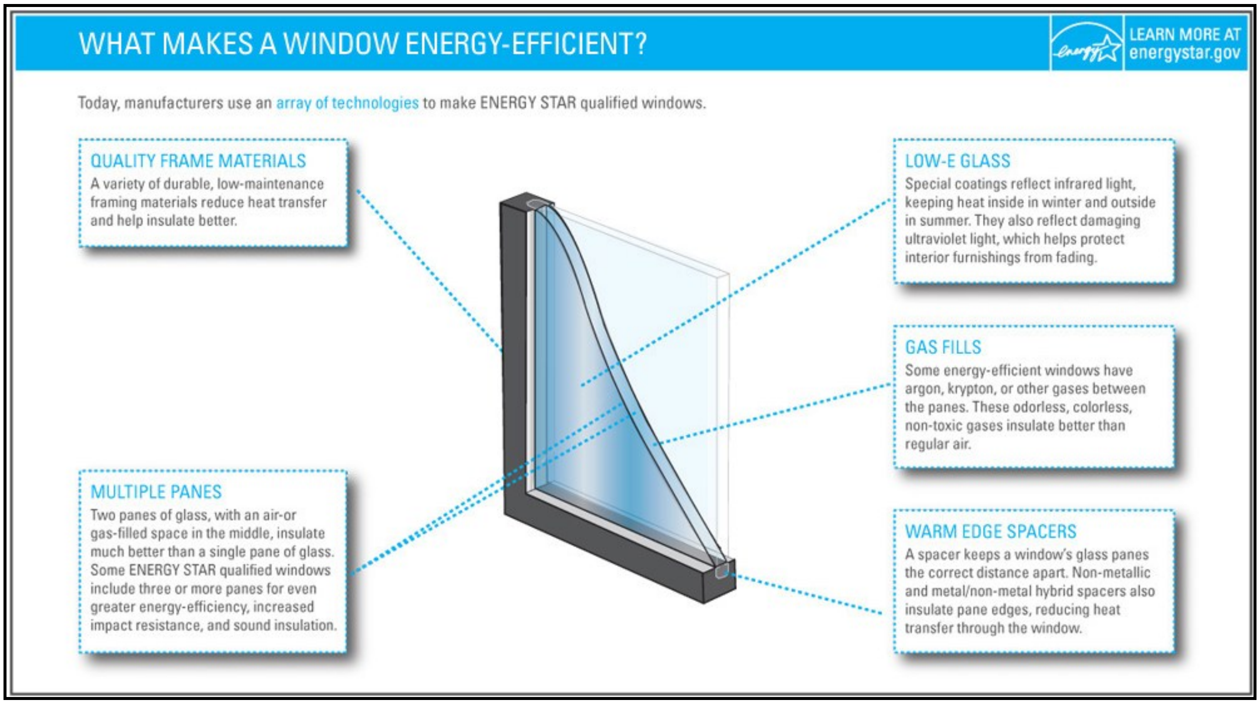
Figure 5.1 Heat Loss Equation (ASHRAE Principles)

$$\mathbf{Q} = \mathbf{A} \times \mathbf{U} \times \Delta\mathbf{T}$$

Q = Heat transfer in Btu/h
A = Area in SF
U = U-value in Btu/h*SF*°F
Δ**T** = Indoor - Outdoor Air temperature in °F

To reduce heat loss through windows, the window's R-value should be increased. The R-value of a wall can be readily increased by adding insulation. Increasing the R-value of a window is more difficult because the materials that insulate the window must be clear. New windows, called insulated glass units (IGUs), have two panes of glass placed closely together but not touching. These panes of glass have films adhered to them and an inert gas between them that increase the R-value as shown in Figure 5.2 (Kinney and Elsworth). Both the films and the gas are clear and it is possible to see through them. However, not all windows are IGUs, and insulating single pane glass windows, such as historic windows, poses a different challenge.

Figure 5.2 Energy Efficient Window



Historic Windows

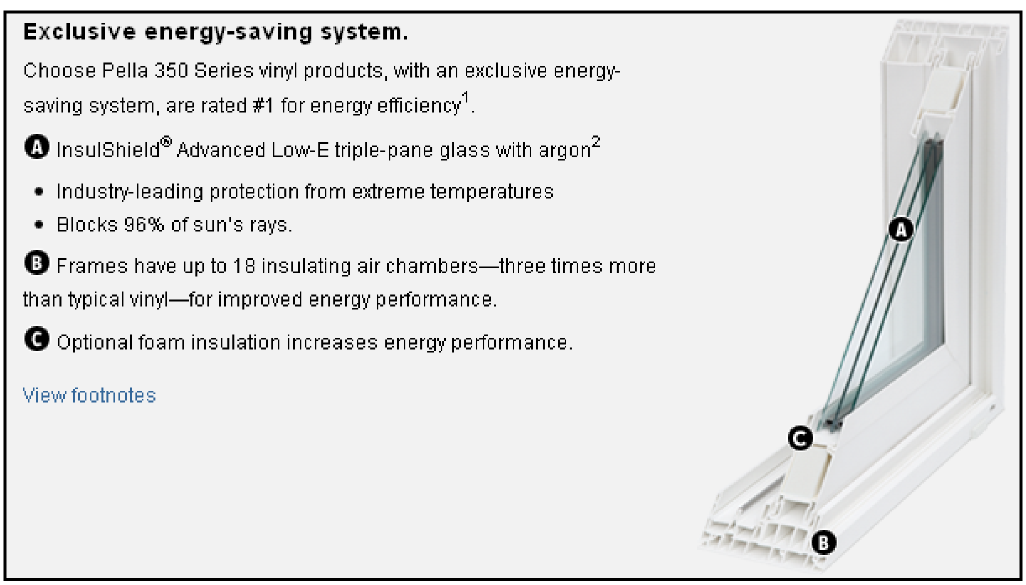
Historic windows are often viewed as the root of most of the energy problems within a home. Window vendors are the first to advise that old windows be replaced with new energy efficient windows and that the energy savings will be such that the windows practically pay for themselves. However, the window itself is not always the root of the problem in regards to energy efficiency. Often, the sealing around the window has aged and is no longer functioning properly. In these instances, resealing around the window will often stop heat loss due to infiltration. "Infiltration, rather than heat loss through the glass, is the principal culprit affecting energy and can account for as much as 50% of total heat loss from a building" (Sedovic and Gotthelf). Often, people replace functional windows in the name of energy efficiency, when resealing is all that is needed to prevent air infiltration. The energy efficiency of a retrofitted window can meet or exceed the energy efficiency of a new window. Unfortunately, when historic windows are replaced, the character and craftsmanship that went into originally producing that window are lost forever.

Historic windows are made from wood and single glass panes. Surprisingly, wood from historic windows is of higher quality than wood used to produce window frames today. Historic windows used hardwoods and softwoods from unfertilized, early growth trees. The wood is denser and has a more naturally occurring grain structure than the wood harvested from fertilized tree farms today (Sedovic and Gotthelf). Windows were also hand crafted without nail guns and adhesives so that the joints in the historic windows are sturdy enough to hold the window together by themselves. Historic windows constructed in this manner have lasted for long periods and many are still functional 100 or more years after they first were installed.

Current Windows

Window technology is constantly changing as more and more manufacturers vie for the prestige of producing the most energy efficient window. Current EnergyStar standards for new windows require a U-factor of 0.3 in the North region of the country (energystar.gov). Regions and associated U-factors for EnergyStar are show in Appendix E. These factors are the maximum values that can be considered EnergyStar rated. Many manufacturers are exceeding these values. Pella®, for example, recently debuted a triple pane glass window, shown in Figure 5.3, with argon gas between each pane, which has a U-factor of 0.17 (pella.com). The U-factor equates to an R-value of 5.88, which is extremely good for a window. When comparing windows, it is important to note that the U-factor that is listed is the value through the center of the glass. U-factors can differ at the edges of the glass and are typically worse than at the center, meaning that a window as a whole might not be as energy efficient as the advertised value would indicate.

Figure 5.3 Pella 350 Series Window (pella.com)



Properly installing new energy efficient windows in a home can decrease a home's heat loss, but the costs of the windows must be considered as well. The cost of installing the best energy efficient windows on the market can be expensive depending on how many windows are being replaced. Standard EnergyStar rated windows, which can be purchased at a home improvement store, will each cost approximately $200. The price does not include the installation cost or the demolition cost (lowes.com). For higher quality windows sold in show rooms, the prices will vary per home. The cost also increases for non-standard sized windows or historic replicas. Quality installation is essential when installing new windows. Often a window opening will not be perfectly square. This requires the contractor to correctly seal around the new window to prevent air infiltration. Even the most energy efficient window will not save energy if it is installed incorrectly. Also, the monetary cost is not the only cost to consider when installing new windows.

In addition to monetary cost, other factors should be considered when determining whether to replace a structure's windows. These factors include resource inputs, production costs, transportation, disposal, and the loss of irreplaceable resources. The total window unit, typically made up of aluminum, vinyl, and glass, requires energy to produce. Energy is needed to produce the materials and to assemble the materials. Sometimes the manufacturing process for window materials, including vinyl and PVC, produces toxic by-products (Sedovic and Gotthelf). When considered comprehensively, the energy cost of manufacturing and installing a new window might be higher than retrofitting an old window. Production costs might also be incurred more frequently for a contemporary window than an historic window. The warranty of a new window is generally 2-10 years (Sedovic and Gotthelf), which is indicative of the fact that an energy efficient aluminum window is not expected to last 100 years, as would be expected of a high-quality historic window. Products degrade over time, particularly plastic components; the lifetime of a synthetic material is relatively short. IGUs fail regularly because the seal that keeps the gas between the panes of glass can break over time as the sealant around the window edge degrades. Without the gas between the glass panes, the insulating properties of the window are greatly reduced. Every window that is replaced translates into energy outlays to produce and install a new window. Additionally, the windows that are being replaced often go directly to landfills, adding to the burden of municipal waste.

Insulating an Existing Window

Window replacement is sometimes unavoidable. When a window is in such a condition that no amount of restoration can repair the original, then it is time to replace the window. However, certain options should be considered before replacing a window. Homeowners have various options to improve the energy efficiency of a window without replacing it completely.

Storm Windows

A storm window is essentially another window that is installed in front of an existing window. Historically, storm windows were used to increase the energy efficiency of a home's windows by providing another layer of protection from the outside elements. Storm windows also protect the interior window from damage. The President's Residence was constructed without storm windows. The single pane construction had a U-factor of 1.0. By installing a storm window the U-value was decreased by 50%, to 0.5. Unlike contemporary windows, storm windows have no special gas inserted between the panes. Nonetheless, the addition of the single pane of glass greatly increased the energy efficiency of the windows.

Window Films

The installation of window films is another means to improve the energy efficiency of an existing window. The application of a window film is the most popular and least invasive way to insulate a window. The film acts as an exterior coating on the glass. Its composition is shown in Figure 5.4. The window film itself is made of layers of vinyl and includes adhesive layers, low emissivity layers, and scratch resistant layers. The film has an associated R-value and can prevent heat from leaving the home, as shown in Figure 5.5. These films can be found at home improvement stores and can also be found in manufacturer's show rooms. The films from the home improvement stores can be cut to size and installed by the homeowner. Other brands are more expensive, are made to size, and are installed by a contractor. Window films are also beneficial for energy savings in the summer. While they keep heat inside the house during the winter, they also keep heat out of the house in the summer. Low-emissivity window films also prevent fading of interior furnishings and reduce glare. Additionally, some window films protect against vandalism by keeping glass shards together after a window is broken. The window films can be applied to every type of glass from historic to contemporary and can be removed if necessary.

Figure 5.4 Window Film Composition (energystar.gov)

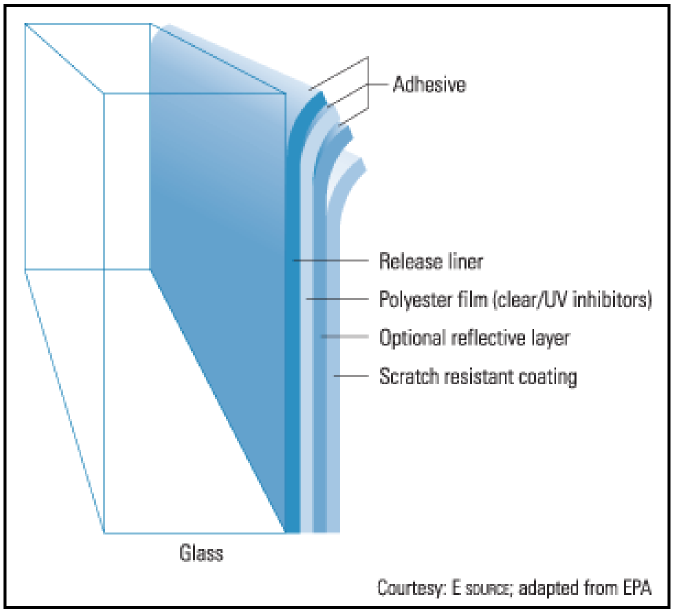
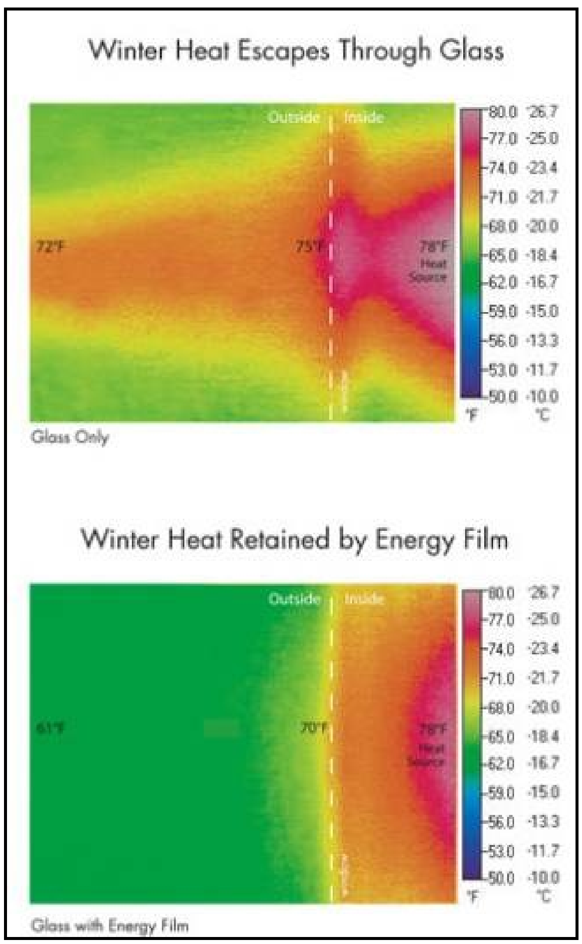


Figure 5.5 Thermal Camera Image of Window (energy-film.com)



Repair

All windows run the risk of being broken, whether by objects such as baseballs or other uncontrollable factors such as debris. However, even if broken, a historic window does not necessarily need to be replaced. Various subcontractors specialize in window restoration. Window frames can be disassembled, the broken pieces, such as a pane of glass, replaced, and the window reconstructed and reinstalled without impacting the historic character of the window. If a window is beyond saving, salvage windows from other historic properties can be used to replace it, or a new replica of the original window can be manufactured. Historically correct repairs can be costly depending on their extent, but the historic window is irreplaceable so every option should be considered before installing new windows in a historic home.

President's Residence Retrofit Options

The last item on the list of energy updates in the President's Residence audit was to replace the windows. The estimated cost for that item was $25,484 and the payback would be 56.4 years. Mr. Robinson detailed in the audit that the item concerning window replacement was added for educational purposes. To compare the cost of replacing the windows to the cost of other solutions, the author calculated the simple payback of Enerlogic window film, Gila window film, and a new window. The price per square foot of Enerlogic window film, including installation, was found on their website, www.enerlogicfilm.com, as well as the U-value. Gila window film can be purchased at Lowes and was priced from the website www.lowes.com. The price data for a new window was taken from the RSMeans 2006 Building Construction Cost Data. The price includes installation but not demolition.

The comparison is shown in Table 5.2. The original window and storm window combination at the President's Residence has a U-factor of 0.5. Adding Enerlogic window film to the window decreases the U-factor to 0.275, making the window the most energy efficient of the options considered. It is interesting to note that adding a window film can reduce the U-factor to a value lower than that of a new window. Decreasing the U-factor is achieved by adding layers of insulating materials. In new windows multiple panes of glass, air spaces, and low-emissivity coatings increase the insulating properties of a window. For existing windows, a window film is an appropriate insulating layer. While glass is a poor insulator, the vinyl of the window film is a good insulator. Low-emissivity window films serve the same purpose as the low-emissivity coatings on a new window, but the window film is thicker than the coating and is a better insulator.

To calculate the energy saved, the author totaled the window square footage and determined the temperature differential from inside of the house to the outside using the design conditions found in the ASHRAE Principles book. The heat loss was calculated in British thermal units per hour (Btuh), but the author changed Btuh into 1,000 cubic feet, or MCF, of energy to compare to the energy audit, which was calculated in MCF. MCF is the typical unit of measurement for determining the amount of natural gas used in a residence. The President's Residence is heated using steam that transfers heat to a heating coil in the AHU by use of a heat exchanger. Residential homes most often use a gas fired furnace for heat, which is the reason that the energy audit calculated the amount of energy needed to heat the home in MCF. The audit essentially estimated the amount of MCF needed to heat the President's Residence if the President's Residence was heated using a gas fired furnace. To compare the research of the author to the estimated MCF stated in the audit, the energy savings was converted from Btuh to MCF. These numbers were multiplied by the $9.50/MCF rate found in the energy audit and the savings per year were calculated. Because the Enerlogic film saved the most energy, it is shown to save the most money in the table.

In addition to the energy savings and associated monetary savings, the author also examined the simple payback of purchasing and installing window films and new windows. The Enerlogic window film costs the most to install likely because it is principally a commercial product. The film has some residential applications but the prices for those projects are not public. The new windows were the second most expensive product to purchase and install. Since the Gila window film is installed by the homeowner, it has no labor cost and was the least expensive overall. The Gila window film had an impressive payback of less than a year, making it the best option, in the author's opinion, to insulate a window. Not only did the film have similar insulating properties when compared to the other options, but it was cost effective and could be installed at the homeowner's leisure. The data shows that the windows in the President's Residence, while not the newest, are still performing well and do not need to be replaced, but that adding window film could improve their performance. Additionally, heat loss through window glass is not the only way that windows are energy inefficient. Air leakage around the window frame may account also for significant energy loss. Regardless of the type of window, window frames should be inspected to ensure that they are sealed properly and that no air can infiltrate around the frame. Windows should also be checked to ensure that they function properly.

Table 5.2 Window Retrofit Comparison

Window Retrofit												
Type	R-Value of Window	Film U-Value	Film R-Value	Total R-Value	Total U-Value	Total Window Area (SF)	ΔT (°F)	Heat Loss (Btu/h)	MCF/hr	MCF/yr	$9.50/MCF	Savings/yr ($)
Original	2	n.a.	n.a	2	0.5	968	71	34364	0.033	293.400	$2,787.30	$0.00
Enerlogic Film	2	0.61	1.64	3.64	0.275	968	71	18900.2	0.018	161.370	$1,533.02	$1,254.29
Gila Film	2	0.82	1.22	3.22	0.3115	968	71	21408.77	0.021	182.788	$1,736.49	$1,050.81
New Window	3.33	n.a.	n.a	3.33	0.3	968	71	20618.4	0.020	176.040	$1,672.38	$1,114.92

Table 5.3 Payback Comparison

Payback				
Type	Cost ($/SF)	Area (SF)	Cost ($)	Payback (yrs)
Enerlogic	25	968	$24,200.00	19.3
Gila	1	968	$968.00	0.9
New Window	18.23	968	$17,655.00	15.8

While only heat can transfer through the glass, air can infiltrate through openings in and around the window frame. If a window is not properly sealed air infiltration can greatly decrease the efficiency of the windows. Air infiltration can be a problem for new homes with new windows, historic homes with old windows, or historic homes with new windows. The degree of air infiltration depends on how well the windows were installed and sealed. Historic homes with old windows will probably have air leaks around the window frame because the materials used to seal the windows when first installed have degraded over time. Historic homes with new windows can also have the same problems with air leakage if the new windows were not installed correctly. Additionally, in historic homes the window openings are not always square and the size of the openings may differ from window to window, which makes installing and completely sealing new windows difficult. Consequently, installing a new window may not necessarily solve all the energy problems associated with air leakage. In many cases, it is more cost effective to re-seal an existing window than to install a new window. Maintaining the existing windows also ensures that the historic character of the original windows is not diminished.

Determining how much air is leaking around a window is difficult unless a blower door test is performed around one window. A blower door test for a home will not identify where the air infiltration is coming from or how much air infiltration is coming from one area. A fog test can better determine the location of the infiltration. The windows in the President's Residence are quite loose and it is assumed that they lose at least 0.6 CFM per square foot, which is twice the U.S. Department of Energy recommended maximum leakage rate of 0.3 CFM per square foot for new windows.

In the President's Residence, if each window was leaking at a rate of 0.6 CFM per square foot it would equate to 45,163 Btuh, or 386 MCF. At a rate of $9.50/MCF, the windows in the President's Residence would cost $3,663.22 per year because of air leakage. If the windows were sealed and the air leakage rate was reduced to 0.3 CFM per square foot of window area it would equate to 22,550 Btuh, or 192 MCF. This amount totals $1,829.06 spent on heating due to air leakage, which is a savings of $1,834.16.

Chapter 6 - Heat Loss

"Heating engineers who wanted a way to relate each day's temperatures to the demand for fuel to heat buildings developed the concept of heating degree days. To calculate the heating degree days for a particular day, find the day's average temperature by adding the day's high and low temperatures and dividing by two. If the number is above 65, there are no heating degree days that day. If the number is less than 65, subtract it from 65 to find the number of heating degree days" (noaa.gov). The concept of heating degree days is expressed in the equation in Figure 6.1. Using degree days of a building to estimate the energy use can help building owners estimate and compare different heating and cooling systems for a building. The equation shows the amount of energy a system will use each month depending on how hot or cold it is expected to be. The more extreme the temperature difference between the inside of the building and the outside, the more energy will be spent conditioning the interior space. The equation also takes into account the efficiency of a piece of equipment so that different pieces of equipment can be compared for the same location or the same piece of equipment can be compared in different applications.

Figure 6.1. Degree Day Equation

$$E = \frac{q_L \text{ (DD) } 24}{\eta \text{ (HV) } \Delta t} C_D$$

E = fuel or energy consumption for the estimate period, units of fuel

q_L = design heat loss, including infiltration and ventilation, Btu/h

DD = number of degree-days for the estimate period

Δt = design temperature difference, °F

η = efficiency of a heating system, also designated on an annual basis as the annual fuel utilization efficiency (AFUE)

HV = heating value of fuel, Btu/unit of fuel

C_D = .77 if 65°F is arbitraryily assumed as the balance temperature

For the President's Residence, the author completed a Degree Day Calculation to determine the heat loss from the building and to determine the efficiency of the residence's heating. According to ASHRAE's Principles of Heating, Ventilating, and Air Conditioning, degree day calculations are one of the “simplest methods for energy analysis.” The method depends on the concept that energy use depends only on the temperature difference between the inside and outside of the building. This concept makes the degree day method work well for small structures but it is not relevant for large commercial buildings. Because the President’s Residence is a smaller structure, it was appropriate to use a degree day calculation instead of a computerized model to evaluate the heat loss.

The energy audit results showed that there was a large amount of infiltration into the President’s Residence, which contributed to heat loss and made the heating equipment work harder. Using a spreadsheet developed using the concepts from ASHRAE’s Principles of HVAC, the total heating load of the building was estimated. The spreadsheets can be found in Appendix B. The calculations included heat loss through walls, windows, doors, floors, and roof. The infiltration rate used in the spreadsheet was the calculated infiltration rate from the blower door test.

Four spreadsheets were created. One used the original data gather from the audit. The second spreadsheet used the same data for the residence, but the infiltration rate used was 0.41 ACH instead of the calculated 1.17 ACH. In the audit, Mr. Robinson explained that the goal of the energy audit was to reduce the infiltration rate by 65%, which equals 0.41 ACH. There was not an opportunity to conduct another blower door test after the service project was completed, so an actual ACH rate could not be determined. The third spreadsheet incorporates the window U-value change from Chapter 5. Using the Gila window air film reduces the heating load of the windows and ultimately the overall heating load of the residence. The final spreadsheet incorporates both the new window U-value and the goal ACH rate.

After these spreadsheets were created, another spreadsheet was developed by the author using the equation in Figure 6.1. This spreadsheet incorporated the different heating loads and, with the degree days and the temperature differential, calculated the MCF needed for each month and a total MCF savings for the year. The results of this spreadsheet are shown in the graph in Figure 6.2, Figure 6.3, Table 6.1, and Table 6.2. The full spreadsheet is shown in Appendix C.

The graph of the final results shows that reducing the infiltration by 65% made the largest difference in reducing the MCF consumption. It is interesting to note that adding the window film barely reduced the total MCF used. So while Table 5.2 shows that adding a Gila window film will reduce the total MCF by 110.6 MCF per year, Appendix C shows that the total MCF will only be reduced by 18.4 MCF per year. The reason the numbers vary so greatly between tables is that there is not a 72°F temperature difference between the outside and the inside of a building throughout the entire year. The degree day method takes the average temperatures of the months into account when calculating the total MCF. Inadvertently, the degree day method demonstrates that replacing windows because of U-values is even more unadvisable than stated in Chapter 5.

The heat loss values were calculated as MCF even though the AHUs that provide the house with heat do not use gas heat. Residential homes commonly use gas fired furnaces and in the audit report Mr. Robinson calculated the President's Residence energy usage for the year in MCF. To verify his numbers, the author performed the calculations in MCF to allow a comparison of the two loads. It is also impossible to chart how much energy is used by the AHUs in the President's Residence because they are unmetered. The energy use for the residence is tied in with all the buildings on campus and powered by the power plant.

Figure 6.2 President's Residence Heating MCF Usage

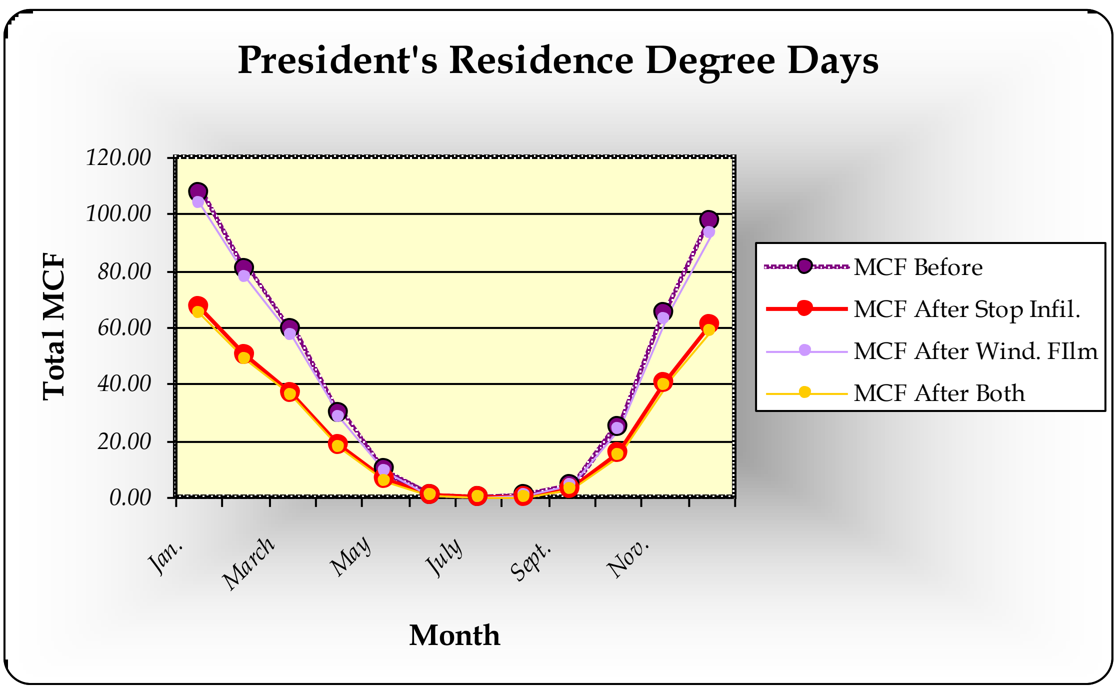


Figure 6.3 Degree Days $ Comparison

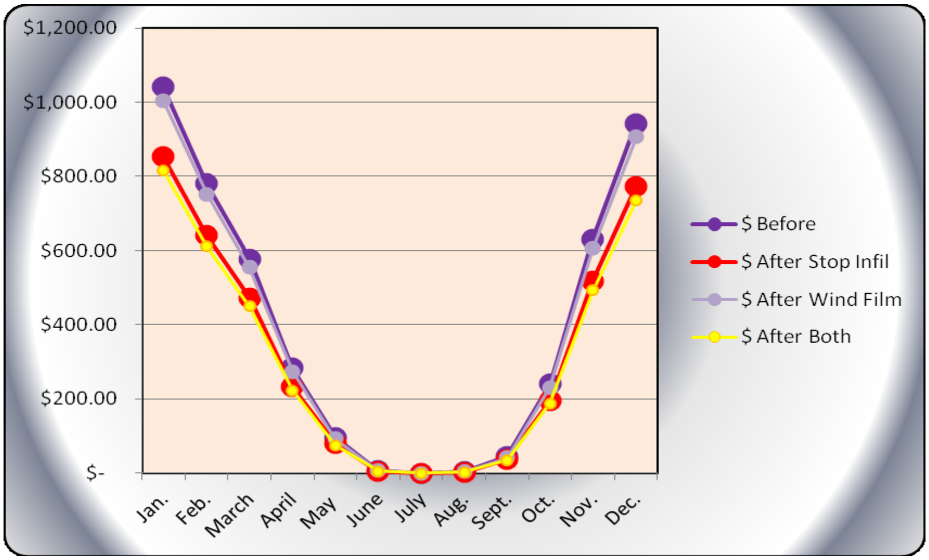


Table 6.1 Degree Days MCF Comparison

Degree Days	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
MCF Before	107.61	80.64	59.45	29.40	9.89	0.65	0.00	0.37	4.48	24.73	65.05	97.25
MCF After Stop Infil.	67.07	50.26	37.06	18.32	6.17	0.41	0.00	0.23	2.79	15.42	40.55	60.62
MCF After Wind. Film	103.48	77.55	57.17	28.27	9.51	0.63	0.00	0.36	4.31	23.78	62.56	93.52
MCF After Both	65.04	48.74	35.94	17.77	5.98	0.39	0.00	0.23	2.71	14.95	39.32	58.78

Table 6.2 Degree Days $ Comparison

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
$ Before	$1,042.84	$781.45	$576.14	$284.90	$ 95.87	$ 6.33	$-	$ 3.62	$ 43.41	$239.68	$630.40	$942.44
$ After Stop Infil.	$ 854.29	$640.16	$471.97	$233.39	$ 78.54	$ 5.19	$-	$ 2.96	$ 35.56	$196.35	$516.43	$772.05
$ After Wind. Film	$1,003.65	$752.08	$554.49	$274.20	$ 92.27	$ 6.09	$-	$ 3.48	$ 41.78	$230.67	$606.71	$907.02
$ After Both	$ 815.11	$610.80	$450.32	$222.69	$ 74.94	$ 4.95	$-	$ 2.83	$ 33.93	$187.34	$492.74	$736.64

Chapter 7 - Other Energy Saving Methods

Many means of saving energy were listed in the audit and discussed in previous chapters, but there are other opportunities to save energy without performing an energy audit. Some ideas are basic behavioral changes, such as turning off a light when leaving a room, but they save energy. Switching the lamps in a home from incandescent to compact fluorescent is another straightforward way to save energy. Switching lamps was largely supported by the Take Charge Challenge and was one of the ways the program determined points for the competition.

Basic Energy Saving Ideas

Various energy saving methods have been considered for many years and are still valuable recommendations. Some common and effective methods to save electricity include the following: turn off lights when not in a room; put lights on a timer when on vacation so that the lights are not on constantly; unplug electronics when not in use; recognize that even though the television or other electronics are off, they are still drawing power; turn the thermostat down or off when no one is home; keep the set point low on the thermostat in the winter and use a space heater if the temperature gets too cold; instead of heating the entire house, heat only used spaces; use fireplaces and recognize that modern and properly installed and maintained gas and wood burning fireplaces can efficiently heat a room.

Other ways to save energy are to protect against the elements: use foam rollers to block the space under doors so that cold air from outside cannot get in the home; in the winter, apply a plastic cover to windows so that cold wind does not blow into the house; install thick curtains over windows to keep out drafts and insulate against the cold in the winter; in the summer, use thick curtains to keep out the sun's rays and prevent them from heating the home.

Lighting

The Take Charge Challenge focused on energy audits for many homes but they also strongly promoted switching incandescent lamps to fluorescent as a cost effective way for homeowners to score points for their city. Each switch gained the city 0.12 points. Although each switch earned only a small amount of points, when added together, these switches generated many points for participating cities. Homeowners were encouraged to replace their lamps and then register the total number of lamps they replaced on the Take Charge website so their points could be counted. In total over all the regions, 320,181 lamps were switched from incandescent to compact fluorescent, which equates to $1,269,365 in energy savings (takechargekansas.org).

Compact fluorescent lamps are more energy efficient than incandescent lamps due to the way they are made. Incandescent lamps produce light by heating a metal filament enclosed inside the glass bulb. This metal filament produces light when it reaches a certain temperature, but it also produces heat. Only 10% of the energy used in an incandescent lamp is used to produce light; the other 90% of the energy is converted into heat, making these lamps very inefficient (popularmechanics.com). Not only is the hot lamp dangerous if touched, it also raises the temperature in a home and can increase the work load of the cooling equipment. Comparatively, compact fluorescent lamps require only 25% of the energy of an incandescent lamp to produce the same light, making them much more efficient. "According EnergyStar, if each U.S. home replaced just one of its incandescent lamps with a CFL, the electricity saved each year could light 3 million homes and prevent greenhouse gas emissions equal to that of 800,000 cars" (popularmechanics.com).

To test these potential energy savings, the author inventoried all the lamps in the President's Residence. Many of the lamps in the light fixtures in the original section of the home had already been switched to compact fluorescent. The lights that still used incandescent lamps were mainly decorative fixtures such as chandeliers or light fixtures with exposed lamps. In the renovated section of the house there were a large number of track fixtures and can lights using parabolic reflector (PAR) lamps. The author also estimated the hours of operation for each room to arrive at a total amount of hours per year that the lamp would be using energy. For example, no lights were anticipated to be in use during the hours of midnight to 6am.

The complete inventory of lights for each room is listed in Appendix D. Changing every lamp in the household to energy efficient compact fluorescent would save 10,704 kWh per year, as shown in Table 7.1. The reduced energy usage would result in a savings of $1,177.44 per year using a utility rate of $0.11 per kWh. The graph of the wattage comparison is shown in Figure 7.1.

Figure 7.1 Wattage Comparison

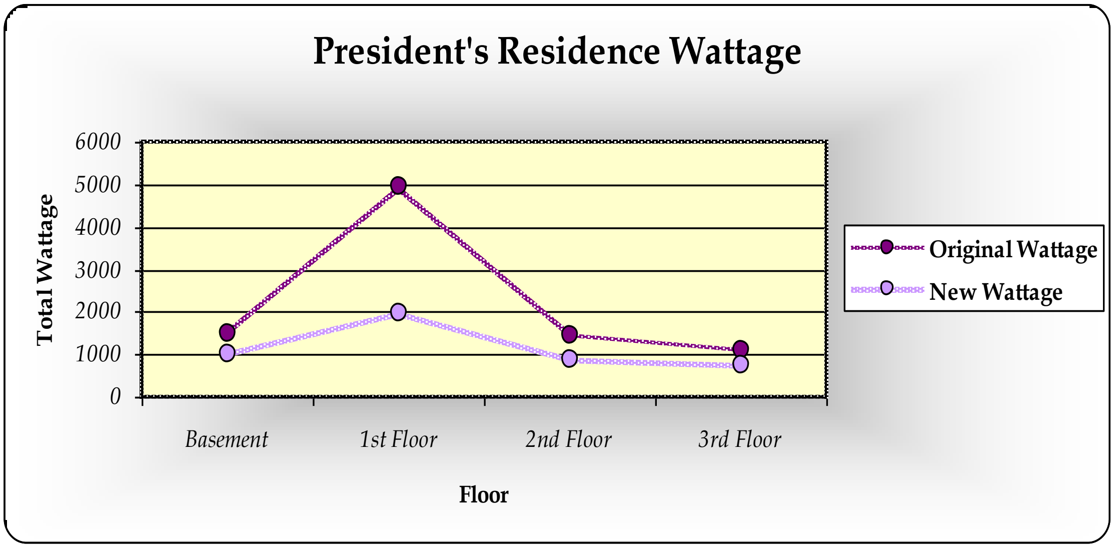


Table 7.1 Wattage Comparison

	Watts Before	Watts After	Wattage Savings
Basement	1471	1009	462
1st Floor	4957	1991	2966
2nd Floor	1433	894	539
3rd Floor	1102	726	376

The housekeeping staff and the president's family have been diligent in replacing incandescent lamps with compact fluorescent lamps in many of the light fixtures. Almost all of the ceiling fixtures have been changed to fluorescent or compact fluorescent lamps and a majority of the table lamps have been changed to compact fluorescent as well. The replacement of the lamps means that there is not as much of an energy savings potential as first anticipated. The area with the most room for improvement is the decorative fixtures. Throughout the residence there are many historic sconces and chandeliers that use incandescent lamps. As the technology for lamps has improved, there are now options to change from an incandescent, decorative lamp to a fluorescent, decorative lamp. However, there are a few issues to reconcile when using compact fluorescent lamps. Among these is that CFLs contain mercury in trace amounts. Instead of throwing these lamps in the trash like a regular incandescent lamp, they should be recycled.

Another opportunity to increase lighting efficiency beyond the use of CFLs is the use of light emitting diodes (LEDs). CFLs solved many of the problems with incandescent lamps when they were introduced. LEDs are now poised to solve some of the problems associated with CFLs. LEDs perform well in most lighting applications, including recessed lighting, and are dimmable. They are also more efficient than CFLs. “For example, Lighting Science Group’s Definity LED delivers 112 lumens per watt compared to a CFL’s 50 to 70 lumens per watt” (popularmechanics.com), demonstrating that LEDs produce more light using less wattage than CFLs. One prohibitive aspect of LED lamps is their price. Even though the life span of an LED is 25,000 hours, or a total of three years, the price of the individual lamp is approximately $30 to $50. The price is expected to drop in the next few years as more manufacturers produce the product (popularmechanics.com), allowing LEDs to challenge CFLs in regards to energy efficiency.

Chapter 8 - Conclusion

Energy conservation has emerged as one means to address regional and global environmental challenges. At times it can be difficult to see how the actions of one person can impact energy consumption or address regional and world challenges. However, the actions of many individuals can collectively achieve significant results. The Take Charge Challenge is designed to showcase such results to the people who most need to see them, the energy consumers. The goal of the Take Charge Challenge in Kansas is to motivate families across the state to save as much energy as possible in their homes while engaging in a friendly competition with other cities. Through energy efficiency updates to their homes, the Challenge shows residents how to reduce energy consumption, increase the comfort and functionality of their homes, and achieve cost savings.

To determine areas of potential energy savings in each home, an energy audit is performed to pinpoint areas of energy loss. An audit report summarizes the results and provides a list of energy efficient upgrades. The items on the list are organized from most cost effective to least cost effective based on a whole house approach, which focuses on the fact that many different factors affect the energy performance of a home. The approach addresses the most critical needs first, which are not always the most obvious. Noel Shultz, the first lady of Kansas State University, participated in the Take Charge Challenge and had her home, the President's Residence, audited to improve the energy efficiency of the building and set an example for the community.

The Kansas State University's President's Residence is a relatively old building. Although it was built to the standards of the early 1900s and has been updated since that time, many of the original features of the building are now contributing to energy loss. A summary of the energy problems of the house was compiled in the energy audit, which detailed problem areas and proposed solutions to these problems.

Some of the solutions detailed in the audit would be costly to implement due to the scope of the work and would require outside aid through loans. Other improvements could be undertaken at a relatively minimal cost. Minimal cost items include the replacement of incandescent lamps with compact fluorescent lamps in light fixtures and the sealing of cracks around windows and doors to prevent air infiltration and leakage. These updates may at first appear small and insignificant but can result in significant savings. The Take Charge Challenge recognizes the cumulative impact of numerous minor improvements and awards points for such actions, such as changing individual lamps in a home to compact fluorescent. The program demonstrates that even small measures make a difference in a home's energy usage especially when a family does not have the funds to make more costly improvements.

The results of the President's Residence audit posed some complications due to the age of the home. The software used to compute the energy savings of the house assumed that the structure was built using contemporary materials and products. Such an assumption is not accurate for the President's Residence and other older structures on the Kansas State University campus and within the State of Kansas. One of the most significant differences between the President's Residence and the model was the wall construction. The walls of the President's Residence are constructed of thick stone, unlike the wood frame walls of contemporary homes. Additionally, the heating and cooling equipment in the President's Residence is different than the gas fired furnace used in the energy audit software. Given the differences between the house and certain model assumptions, various results and recommendations contained in the audit should be qualified.

Additionally, as an historic property, alterations should respect the architectural integrity of the house and be researched in depth. There are many historic features to a home that could be damaged if not considered properly, such as exterior masonry walls, plaster interior walls, windows, and joists. The same technique used to upgrade a common, residential home might not be appropriate for an historic property. For example, blowing insulation between an exterior masonry wall and interior plaster might damage the plaster irreparably and create the potential for mold. Such a process, while effective for a suburban home, would have far reaching consequences if performed on an historic home. While certain types of updates could be performed, all projects should be carefully researched before being starting.

The author performed an in depth analysis of the energy audit and compared its estimated energy savings to the author's calculations. The author looked at the energy savings of replacement windows and found that replacing the historic windows would not only destroy the historic character of the windows but would not be a cost effective solution. Instead, installing a low-emissivity window film and properly sealing any cracks around the windows would improve the energy efficiency of the old windows to a level comparable to a new window. The author also analyzed the replacement of incandescent lamps in the residence with compact fluorescent lamps. Compact fluorescent lamps are now produced in decorative styles so that historic light fixtures as well as contemporary fixtures can use compact fluorescent lamps and save energy.

To begin the updates on the President's Residence, material was donated by Kansas State University's Facilities Department. Volunteers from Kansas State University's Architectural Engineering Institute (AEI) and Associated General Contractors (AGC) student chapters, along with faculty, installed the donated material in some of the problem areas identified in the energy audit. These service projects helped students gain practical experience and offered the University a cost effective means to realize significant energy and monetary savings. After the service project was completed, the author took thermal images of the residence and compared them to thermal images taken before the service project. There was a marked reduction in heat loss through the roof when comparing the two images.

Based on the success of the Take Charge Challenge and the improvements to the President's Residence, the University should consider the expansion of these efforts. One of the first steps in an expansion should be a systematic and comprehensive assessment of campus buildings to determine where improvements would be most cost effective. The assessment should consider the age of the buildings. Model parameters could be modified to more accurately reflect historic construction materials and techniques. Historic buildings could be inventoried in coordination with the SHPO. Monitoring should also be completed to demonstrate the effectiveness and the savings over time for the chosen improvements. Service projects should continue, as a means for students to gain field experience.

Already the benefits of the improvements to the President's Residence, including new insulation, sealant, and weather stripping, can be seen in thermal images and felt by the family. It is the expectation that these improvements and others will improve the efficiency of the President's Residence and reduce energy costs. Such improvements can then serve as an example to the campus and the surrounding community of the difference that energy improvements can make.

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Appendix A - Energy Audit

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Energy Audit Report

KSU, Division of Facilities, C/O Casey Lauer
100 Wilson Ct
Manhattan, KS 66506

Tuesday, March 08, 2011

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KSU, Division of Facilities, C/O Casey Lauer, 100 Wilson Ct, Manhattan, KS 66506

BuildingPerformanceCo.
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Gypsum, KS 67448
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Dear KSU, Division of Facilities, C/O Casey Lauer,

Thank you for the opportunity to audit your home. I hope you will find the following report informative and helpful for any future plans you may have for your home.

There are many scientific calculations, theories, and test results that support the data for a comprehensive energy audit. We have tried to distill that information into a short synopsis that shows the results clearly. If you would like additional information on how we arrived at our conclusions, please feel free to contact your Building**Performance**Co. analyst any time.

In order to provide you with a complete picture of your home, Building**Performance**Co. considers the following four categories: safety, durability, energy, and global environment. The first three categories deal directly with our immediate environment and indirectly with the global environment. If Building**Performance**Co. can increase your quality of life or work by increasing your safety, increasing the longevity of your building, and save you money through energy savings we will help you do your part for global sustainability and the environment. Safety includes issues that do, or could, make your home unsafe to reside in, including indoor air quality and moisture/mold. Durability includes variables that will make your home last as long as possible. Energy pertains to opportunities that will enable your home to be more efficient, operating more cost effectively. Environment shows how your home affects the global environment through emissions from energy consumption.

We would also like to stress the importance of acting on the information contained in this report. The money you spend on obtaining this information and the effort we collectively put into producing this information is wasted unless it is acted upon. If you would like help implementing the following recommendations we would be glad to help. In the greater Salina area we provide General Contractor services as well as contractor referrals. If you are outside the Salina area or you prefer to act as your own contractor we would be glad to help guide you in your decision making processes.

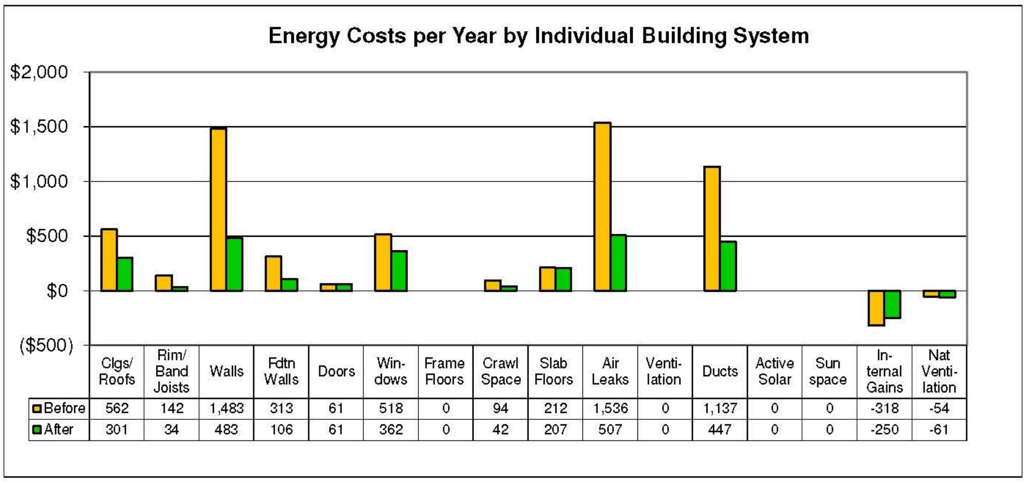
The following bullets summarize the results of the energy audit performed at 100 Wilson Ct, Manhattan, KS

- Safety - None Noted
- Durability – None Noted

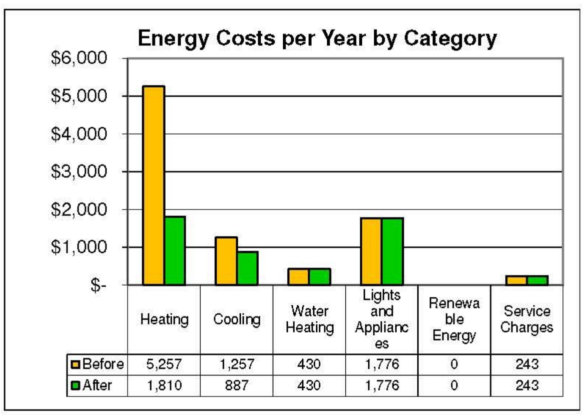
• Energy - You will find our recommendations for energy efficiency upgrades on the "Cost Effective Energy Upgrade" Table. Air sealing measures and a discussion about air infiltration in your home can be found on the "Air Sealing Action Areas" Sheet.

See "General Notes" below and "**Efficiency Kansas Loan Calculations**" Sheet for more information concerning the Efficiency Kansas loan program.

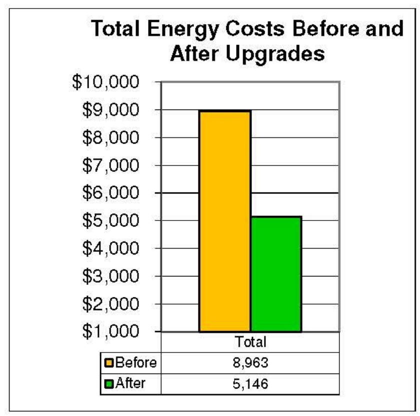
The following charts summarize energy savings based on current energy consumption and after suggested improvements.



	Clgs/ Roofs	Rim/ Band Joists	Walls	Fdtn Walls	Doors	Win-dows	Frame Floors	Crawl Space	Slab Floors	Air Leaks	Venti-lation	Ducts	Active Solar	Sun space	In-ternal Gains	Nat Venti-lation
Before	562	142	1,483	313	61	518	0	94	212	1,536	0	1,137	0	0	-318	-54
After	301	34	483	106	61	362	0	42	207	507	0	447	0	0	-250	-61



	Heating	Cooling	Water Heating	Lights and Appliances	Renewable Energy	Service Charges
Before	5,257	1,257	430	1,776	0	243
After	1,810	887	430	1,776	0	243



	Total
Before	8,963
After	5,146

Refrigerator and Freezer Information				
	Model	Current Model KWH/yr	ENERGY STAR Model KWH/yr	Savings [1] $/yr
Refrig 1	Subzero 56	945	518	$47
Refrig 2	Kenmore No tag			$
Refrig 3	True soda cooler No Tag			$
Refrig 4	Wine Cooler No Tag			$
Freezer 1	Kenmore 198.8185380	955	427	$58
Freezer 2				$
Freezer 3				$

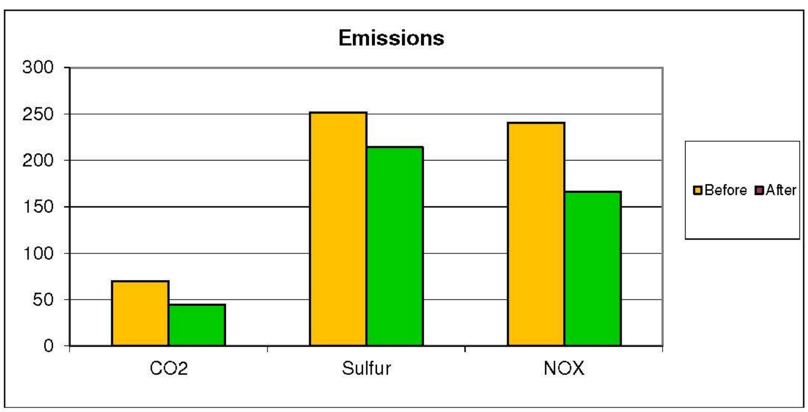
Refrigerators and other energy consuming products not physically tied to the building do not qualify for Efficiency Kansas loan funds. 1 Savings based on difference in energy usage from current model to ENERGY STAR model and your average electric rate over the last year.

The following table outlines the specifications of 100 Wilson Ct, Manhattan, KS 66506:

Area:	7200
Volume:	64342
Year Built:	1910
Number of bedrooms:	5
R-value of walls:	Unins
R-value of ceiling:	13 & 25
Efficiency of furnace/Boiler:	90 & 80 AFUE
Efficiency of a/c:	10 SEER

AFUE: Annual Fuel Utilization Efficiency
SEER: Seasonal Energy Efficiency Ratio

• Environment – The following chart summarize the current emissions of your building before and after suggested improvements. These emissions are produced as a byproduct of combustion when burning carbon based fuels such as natural gas, propane, and coal.



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General Notes:

1) The "Accepted Contractor Bid" column on the "Cost Effective Energy Retro-Fit Table " on the following page will be changed to reflect actual costs from bids you receive from contractors (or material bids if you are doing work yourself). Submit final bids to your Building Performance Co. analyst for insertion into the Retro-Fit Table. If all the items on the report cost more than your maximum loan amount (based on "Efficiency Kansas Loan Calculations") you will have to come up with the difference. We will make the submittal to Efficiency Kansas.

2) Work must be completed in the order shown on the "Cost Effective Energy Retro-Fit Table ". For example: If item 1 is Insulating an attic space, and Item 5 is replacing a furnace - Item 5 can not be completed without completing item 1. However, Item 1 can be completed without completing item 5. Item 5 would not have to be completed, but if item 5 is completed items 1-4 also have to be completed.

3) Davis Bacon Wage reporting is only required for businesses, so ignore any such references in residential settings. Efficiency Kansas has not had a chance to change their forms yet.

4) The Maximum loan amount is $20000 for residences and $30,000 for Small Businesses

5) See "Efficiency Kansas Loan Calculations " for details on loan amount you qualify for.

6) Do it Yourself (DIY) terms and conditions form must be filled out for anyone self performing any work for the Efficiency Kansas program. Contractor Terms and Conditions Forms must be filled out by each contractor and submitted with bids. Forms are attached following "Cost Effective Energy Retro-Fit Table ".

7) DIY guidelines are available in the program manual if you wish to work on your own home. State historical guidelines are also in the program manual if you wish to use Efficiency Kansas loan money to alter the exterior of your home (i.e. windows).

8) Contractors should be encouraged to bid on any or all line items on the "Cost Effective Energy Retro-Fit Table". It would be expedient if contractors would break down their bids into line items as shown. We would be happy to speak with any contractor about the specifics of any line item.

Again, please feel free to contact your Building Performance Co. analyst at any time. We would be glad to answer any questions you may have.

Chad Robinson
President
Building Performance Co.
(785) 787-0180
crobinson@buildingperform.com
Visit us on the web at www.buildingperform.com

Notes to Efficiency Kansas Loan Program participants:
Liability
The Kansas Corporation Commission (KCC) does not endorse, approve, or recommend any energy auditor, contractor or subcontractor associated with the Audit Report, or energy efficiency improvements. No guarantees or warranties, express or implied, are made by the KCC or the Kansas Energy Office with respect to any audit report, estimated savings, proposal for improvements, contract for improvements or any work or equipment included as part of the customer's energy efficiency project funded through the Efficiency Kansas revolving loan program. It is recommended that customers exercise due diligence in the selection of an energy auditor or contractor prior to entering into any contract or agreement for energy efficiency improvements.

Customers may request references of an energy auditor or contractor and should always insist that any guarantees and warranties represented by an energy auditor or contractor, either for workmanship or equipment warranties, are provided in writing. The KCC and the Energy Office are not liable for any intentional, criminal, or negligent acts or omissions of the auditor or contractor. The KCC and the Energy Office make no representation of warranty of any kind, expressed or implied as to the quality of the work done by independent energy auditors.

Audit Expiration
Audits and Energy Conservation Plans shall expire one (1) year from the date printed on the audit report. Customers who do not elect to move forward with a project during this time frame will be required to have another audit, should they wish to access Efficiency Kansas financing through either the bank or utility track.

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Efficiency Kansas Loan Calculations

KSU, Division of Facilities, C/O Casey Lauer, 100 Wilson Ct, Manhattan, KS 66506

Maximum Efficiency Kansas Loan Amounts

Cost Effectiveness Calculations

Savings per month ($):	318.08	From "**Cost Effective Retro-Fit Table**"

Utility Track

Weststar "Simple Savings"		
Max loan ($):	50,919	$20,000 Maximum
Customer Buydown Required for full	0	

Includes reductions for $2 monthly SEO 10% energy savings and $1.39 per month utility fee

EnergyTrax

Beloit, Horton, Sabetha	
Max loan ($):	50,465
Required for full project	0

Includes reduction for $2 monthly SEO Fee, 10% energy savings, $1 per month utility fee, and applicable EnergyTrax fees.

Bank Track

Max loan ($):	57,255	$20,000 Maximum
Required for full project	0	

Does not include $2.00 State Energy office Fee, or interest.

Note: Utility Savings may not cover monthly payments with this option

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Cost Effective Energy Upgrade Table Option 1

Action Area	Description of Work (for KSU, Division of Facilities, C/O Casey Lauer, 100 Wilson Ct, Manhattan, KS 66506)	Estimated Cost ($) [2]	Customer Buydown	Savings ($/yr)	Simple Payback
Thermo-stats	Install programmable thermostats and use them!	$150	-	$96	1.6
Air leakage	Reduce air leakage to 5000 CFM50. (about 65%) . See infiltration sheet for more information.	$4,320	-	$1,198	3.6
Above grade walls	Dense blow cellulose insulation into uninsulated exterior walls. 4454 sq ft including 1000 sq ft of windows and 180 sq ft of doors. Fill/plug upstairs joist, See EKMIM pg 21-28.	$8,044	-	$1,374	5.9
	The above line item is somewhat theoretical for purposes of this report. The intent is to show what the savings would be if the wall were insulated.				
	Although we understand that implementing this suggestion would be quite difficult and more costly than stated. A house that could be easily retrofitted to insulate the walls would realize this savings.				
Ceiling	Blow R-26 in on top of R-13 above 3rd floor. Straighten out batts above 2nd floor and blow in insulation to R-38. Blow in R-38 on floor of uninsulated cavities beside 3rd floor walls. See EKMIM pg 9-14	$1,325	-	$211	6.3
Above grade walls	Install R-13 batts on all uninsulated kneewalls on the 3rd floor. Access will need to be cut into 4 areas that are inaccessible.	$812	-	$139	5.8
Basement Walls	Install min R-10 insulation on exterior Basement walls. Insulation must be vapor permeable. Consider using spray foam to air seal the rock walls. (1240 Sq ft) See EKMIM pg 33-36.	$4,493	-	$347	12.9
Crawl Space	Install min R-10 insulation on exterior Crawl walls. Insulation must be vapor permeable. Consider using spray foam to seal the rock walls. (152 sq ft) See EKMIM pg 33-36.				
Rim Joist	Install R-19 insulation in Uninsulated rim joists above exterior walls (231 linear ft) (Do not insulate Bsmt to Crawl wall and rim). Consider using Spray foam for a better seal. See EKMIM pg 37-38.				
Crawl Space	Install minimum 6 mil plastic on crawl space floor to prevent moisture migration into house. Seal plastic to walls and piers. (524 sq ft) See EKMIM pg 33-35	$450	-		
Windows	Replace all single pane windows with Energy Star rated windows. Note the 56 year payback, again this item is included for education purposes.	$25,484	-	$452	56.4
		$45,078		$3,817	11.8

[2] Costs can vary tremendously depending on contractors and regional differences. Please only use the Cost column as a very loose reference.

Simple Payback is the Estimated Cost divided by Savings, or the amount of time required for the energy savings to pay back the initial cost of the improvement.

Customer Buydown is the out of pocket expense to perform this item and the items above it on the list (based on estimated costs and allowable utility track loan see Efficiency Kansas Loan Calculations page) .

EKMIM - Efficiency Kansas Material and Installation Manual can be found at www.efficiencykansas.com/contractors.php

Building Performance Co. analysts are not financial or tax advisors please contact your financial or tax advisor for professional advice on what may be cost effective for you.

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Cost Effective Energy Upgrade Table Option 2

Action Area	Description of Work (for)	Estimated Cost ($) [2]	Customer Buydown	Savings ($/yr)	Simple Payback
Thermo-stats	Install programmable thermostats and use them!	$150	-	$96	1.6
Air leakage	Reduce air leakage to 5000 CFM50. (about 65%) . See infiltration sheet for more information.	$4,320	-	$1,198	3.6
Above grade walls	Dense blow cellulose insulation into uninsulated exterior walls. 4454 sq ft including 1000 sq ft of windows and 180 sq ft of doors. Fill/plug upstairs joist, See EKMIM pg 21-28.	$8,044	-	$1,374	5.9
	The above line item is somewhat theoretical for purposes of this report. The intent is to show what the savings would be if the wall were insulated.				
	Although we understand that implementing this suggestion would be quite difficult and more costly than stated. A house that could be easily retrofitted to insulate the walls would realize this savings.				
Ceiling	Blow R-26 in on top of R-13 above 3rd floor. Straighten out batts above 2nd floor and blow in insulation to R-38. Blow in R-38 on floor of uninsulated cavities beside 3rd floor walls. See EKMIM pg 9-14	$1,325	-	$211	6.3
Above grade walls	Install R-13 batts on all uninsulated kneewalls on the 3rd floor. Access will need to be cut into 4 areas that are inaccessible.	$812	-	$139	5.8
Basement Walls	Install min R-10 insulation on exterior Basement walls. Insulation must be vapor permeable. We prefer the use of foam board with a fire resistant cover such as drywall. (1240 Sq ft) See EKMIM pg 33-36.	$4,493	-	$347	12.9
Crawl Space	Install min R-10 insulation on exterior Crawl walls. Insulation must be vapor permeable. We prefer the use of foam board. (152 sq ft) See EKMIM pg 33-36.				
Rim Joist	Install R-19 insulation in Uninsulated rim joists above exterior walls (231 linear ft) (Bsmt to Crawl wall and rim does not need to be insulated). See EKMIM pg 37-38.				
Crawl Space	Install minimum 6 mil plastic on crawl space floor to prevent moisture migration into house. Seal plastic to walls and piers. (524 sq ft) See EKMIM pg 33-35	$450	-		
		$19,594		$3,365	5.8

[2] Costs can vary tremendously depending on contractors and regional differences. Please only use the Cost column as a very loose reference.

Simple Payback is the Estimated Cost divided by Savings, or the amount of time required for the energy savings to pay back the initial cost of the improvement.

Customer Buydown is the out of pocket expense to perform this item and the items above it on the list (based on estimated costs and allowable utility track loan see Efficiency Kansas Loan Calculations page) .

EKMIM - Efficiency Kansas Material and Installation Manual can be found at www.efficiencykansas.com/contractors.php

Building Performance Co. analysts are not financial or tax advisors please contact your financial or tax advisor for professional advice on what may be cost effective for you.

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Utility Bill Data

KSU, Division of Facilities, C/O Casey Lauer, 100 Wilson Ct, Manhattan, KS 66506

Utility bill analysis includes all costs that fluctuate with usage in the "Usage Charge[1]". All costs that are consistent from month to month are included as a "Service Charge[2]".

Electricity

		Total KWH	Days in Billing Cycle	KWH/day	Usage Charge [1]	Service Charge [2]	Total Bill	$/KWH
Jan	2010							
Feb	2010							
Mar	2010							
Apr	2010							
May	2010							
Jun	2010							
Jul	2010							
Aug	2010							
Sep	2010							
Oct	2010							
Nov	2010							
Dec	2010							
		0	0	0.0	$ -	0	$ -	#DIV/0!

Gas

		Total MCF	Days in Billing Cycle	MCF/day	Usage Charge [1]	Service Charge [2]	Total Bill	$/MCF
Jan	2010							
Feb	2010							
Mar	2010							
Apr	2010							
May	2010							
Jun	2010							
Jul	2010							
Aug	2010							
Sep	2010							
Oct	2009							
Nov	2009							
Dec	2009							
		0	0	0.00	0	0	$ -	

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Average Rates include all Usage Charges

Average Electric Rate	
0.11000	$ / KWH
Average Gas Rate	
9.50	$ / MCF
Average Cost of Wood	
200.000	$ / Cord

One Year Electric Usage		
Total	42221.00	KWH
One Year Gas Usage		
Total	519.00	MCF

One Year Elect Usage Charge		
Total	$	3,796.00
One Year Gas Usage Charge		
Total	$	4,924.00
One Year Total Usage Charge		
Electric	$	3,796.00
Gas	$	4,924.00
Wood	$	-
Total	$	8,720.00

		From Utility Bills		From REM* Before Upgrades	After Upgrades
Gas Heat (MCF / Yr)		Gas Heat ($ / yr)			
519	MCF	$4,931		$5,257	$1,810
Wood (Cord /yr)		Wood Heat ($ / yr)			
0	Cord	$0			
Elect Heat & Heat related Elect loads (KWH/yr)					
0		$0	per yr		
Cooling (KWH / yr)		Cooling ($ / yr)			
0	KWH	$0		$1,257	$887
Gas Water Heat (MCF/ Day)		Gas Water Heat ($ / yr)			
0.06	MCF	$0		$430	$430
Electric Water Heat (KWH/ Day)		Elect Water Heat ($ / yr)			
0		$0			
Lights & Appliances KWH / Day		Lights & Appliances ($ / yr)			
19.90	KWH	$0		$1,776	$1,776
Renewable Energy KWH / Day		Renewable Energy ($ / yr)			
	KWH	$0			
Service Charge Total		$0		$243	$243
Cost of Energy (W/ SC)		$ 4,931		$ 8,963	$ 5,146

Energy Density	
$/Sq ft	$ 1.21
KWH/Sq ft	5.86
MCF/Sq ft	0.07
$/ ft^3	$ 0.14
KWH/ ft^3	0.656
MCF/ ft^3	0.008

Savings per year After Upgrades: $ 3,817.00

NOTE: Energy modeling software tends to overestimate utility bills on on older homes. Since we do not have actual utility bills to compare, savings estimates may be overstated.

* REM is the energy analysis software used for Efficiency Kansas Energy Audits.

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Graphical Representations of Utility Bill Data

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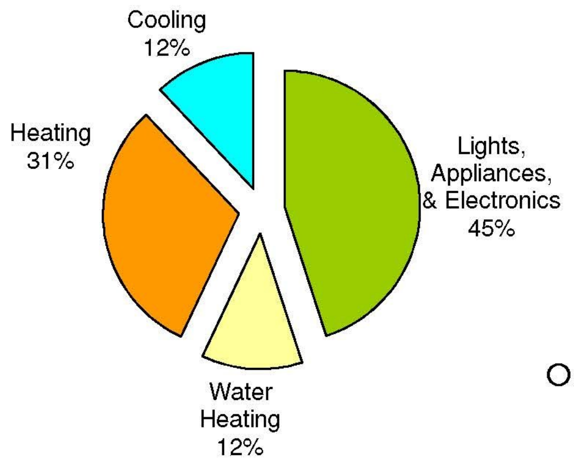
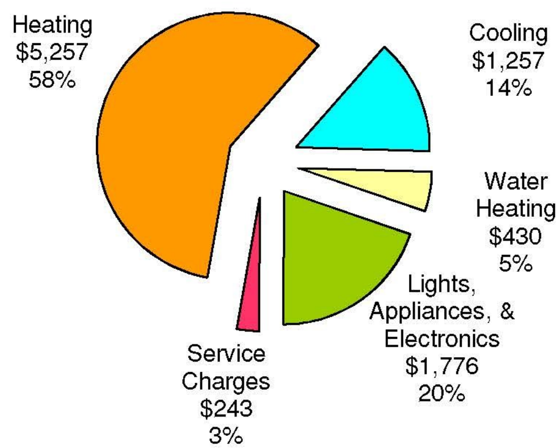
National Average Cost of Energy per Year



One Year Total Usage Charge



A Comparison of your utility bills to the national average. (Comparison only applicable for Residences)

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Contractor Specifications

KSU, Division of Facilities, C/O Casey Lauer
100 Wilson Ct
Manhattan, KS 66506

Tuesday, March 08, 2011

Contractor Specifications
- Cost Effective Upgrade Table,
- Self Performance Terms and Conditions,
- Contractor Terms and Conditions, Pictures, Plan Views,
- Infiltration Action Areas, Equipment Sizing Summary

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Cost Effective Energy Upgrade Table

Action Area	Description of Work (for KSU, Division of Facilities, C/O Casey Lauer, 100 Wilson Ct, Manhattan, KS 66506)	Contractor Bid ($)	Customer Buydown	Savings ($/yr)	Simple Payback
Thermo-stats	Install programmable thermostats and use them!		-	$96	
Air leakage	Reduce air leakage to 5000 CFM50. (about 65%) . See infiltration sheet for more information.		-	$1,198	
Above grade walls	Dense blow cellulose insulation into uninsulated exterior walls. 4454 sq ft including 1000 sq ft of windows and 180 sq ft of doors. Fill/plug upstairs joist, See EKMIM pg 21-28.		-	$1,374	
	The above line item is somewhat theoretical for purposes of this report. The intent is to show what the savings would be if the wall were insulated.		-		
	Although we understand that implementing this suggestion would be quite difficult and more costly than stated. A house that could be easily retrofitted to insulate the walls would realize this savings.		-		
Ceiling	Blow R-26 in on top of R-13 above 3rd floor. Straighten out batts above 2nd floor and blow in insulation to R-38. Blow in R-38 on floor of uninsulated cavities beside 3rd floor walls. See EKMIM pg 9-14		-	$211	
Above grade walls	Install R-13 batts on all uninsulated kneewalls on the 3rd floor. Access will need to be cut into 4 areas that are inaccessible.		-	$139	
Basement Walls	Install min R-10 insulation on exterior Basement walls. Insulation must be vapor permeable. Consider using spray foam to air seal the rock walls. (1240 Sq ft) See EKMIM pg 33-36.		-	$347	
Crawl Space	Install min R-10 insulation on exterior Crawl walls. Insulation must be vapor permeable. Consider using spray foam to seal the rock walls. (152 sq ft) See EKMIM pg 33-36.		-		
Rim Joist	Install R-19 insulation in Uninsulated rim joists above exterior walls (231 linear ft) (Do not insulate Bsmt to Crawl wall and rim). Consider using Spray foam for a better seal. See EKMIM pg 37-38.		-		
Crawl Space	Install minimum 6 mil plastic on crawl space floor to prevent moisture migration into house. Seal plastic to walls and piers. (524 sq ft) See EKMIM pg 33-35		-		
Windows	Replace all single pane windows with Energy Star rated windows. Note the 56 year payback, again this item is included for education purposes.		-	$452	
				$3,817	

Simple Payback is the Estimated Cost divided by Savings, or the amount of time required for the energy savings to pay back the initial cost of the improvement.

Customer Buydown is the out of pocket expense to perform this item and the items above it on the list (based on estimated costs and allowable utility track loan see Efficiency Kansas Loan Calculations page) .

Building Performance Co. analysts are not financial or tax advisors please contact your financial or tax advisor for professional advice on what may be cost effective for you.

All Contractors

Read Efficiency Kansas Material and Installation Manual (EKMIM) prior to bidding to insure compliance with Efficiency Kansas specifications, available at www.efficiencykansas.com/contractors.php

Contractors are encouraged to bid on any or all line items on the "Cost Effective Energy Retro-Fit Table". It would be expedient if contractors would break down their bids into line items as shown. We would be happy to speak with any contractor about the specifics of any line item.

Davis Bacon Wage reporting is required for businesses but not in residential settings.

Under no circumstances will the Kansas Energy Office finance more than the maximum amount approved in the Final Energy Conservation Plan. Contractors' invoices should not exceed accepted bids, unless they have written approval from the customer to deviate from the original bid. All contractors and crew members will be responsible for complying with the EPA's Renovation Repair and Painting (RRP) regulations, as enforced by the Kansas Department of Health and Environment. More information can be found online (www.epa.gov/lead/pubs/renovation.htm).

Contractors should also reference the additional information included in EPA Final Rule [under the authority of 402 c 3 of the Toxic Substances Control Act (TSCA)], and New Lead Based Paint Renovation, Repair and Painting Program requirements (40 CFR 745, Subpart E), issued April 22, 2008 (73 FR 21692).

As noted above, all small business projects funded through the Efficiency Kansas revolving loan program are subject to requirements of the Davis-Bacon and Related Acts (DBRA). Each contractor that provides a bid on a project in a small business is required to provide a signed copy of the Davis-Bacon Acknowledgment form (see Appendix 12 of the Efficiency Kansas Material and Installation Manual).

Self-Performance Terms and Conditions
Efficiency Kansas Loan Program

Customer / Contractor: KSU, Division of Facilities, C/O Casey Lauer, 100 Wilson Ct, Manhattan, KS 66506

I understand that the following are prerequisites:

- Bids must have itemized cost of materials to be used in the energy conservation plan.
- Labor costs will not be covered
- Bids must include total hours worked to complete the project.
- When required in a particular jurisdiction, I must obtain all necessary building permits from the local authority for the work to be performed.
- All bids must state exactly what will be done, so the Kansas Energy Office has documentation for accountability purposes.
- All bids are to be based on the energy conservation plan provided by the auditor, and approved by the State Energy Office.
- All work on homes subject to review under Section 106 of the National Historic Preservation Act,(NHPA) and its implementing regulation 36 CFR part 800 must follow the guidelines as set forth in the Efficiency Kansas Program Manual.
- Material costs are NOT paid in advance.
- No work shall begin until such time as the State Energy Office has approved the appropriate bid and you have been notified in writing.
- All work will be done in a workman like manner and in accordance with industry standards.
- For all commercial & industrial projects; if the cumulative amount of all contracts on a project exceeds $2,000 (including but not limited to labor, materials, and equipment) Davis Bacon prevailing wage rates will apply.
- Only Material costs will be allowed. Purchase of any required tools, licenses or equipment needed to complete the project will not be approved for reimbursement.
- I shall only perform those items of work that are approved by the Kansas Energy Office. I shall not perform any extra work. If prior approval is not granted, the Kansas Energy Office will not be responsible for the additional costs.
- Thermal boundary improvements, such as air-sealing and insulation, must not be installed prior to the correction of or replacement of hazardous conditions existing with mechanical equipment.

I have read and agree to the terms and conditions of the Efficiency Kansas loan program. I understand that any expenses exceeding what was approved by the State Energy Office, or expenses that exceed the maximum award of the program, will not be the responsibility of the State Energy Office.

____________________________ ____________________
Contractor Signature Date

Appendix 10: Contractors Terms and Conditions

Contractor Name :____

Contractor Address: ______________ Phone Number: ____________________________

Customer Name: KSU, Division of Facilities, C/O Casey Lauer Customer Address: 100 Wilson Ct, Manhattan, KS 66

Contractor Terms and Conditions
Efficiency Kansas Loan Program
(Please initial on the space provided after reading each condition)

• I understand that the following are prerequisites for bidding:

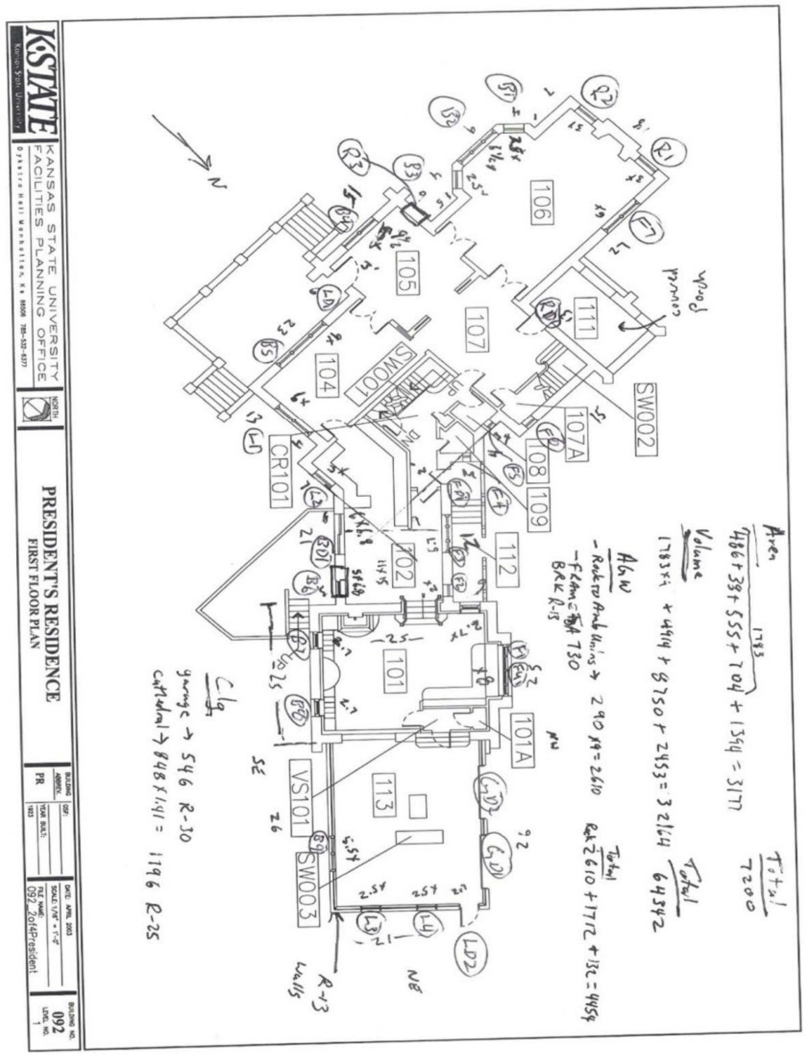
______ Bids must have itemized cost of materials to be used in the energy conservation plan.
______ Labor cost must be listed separately from materials.
______ Bids must include total Man-Hours to complete the project.
______ When required in a particular jurisdiction, I must obtain all necessary building permits from the local authority for the work to be performed.
______ All bids must state exactly what will be done, so the State Energy Office has documentation for accountability purposes.
______ All bids are to be based on the energy conservation plan provided by the auditor, and approved by the State Energy Office.
______ All work on homes subject to review under Section 106 of the National Historic Preservation Act, (NHPA) and it's implementing regulation 36 CFR part 800 must follow the guidelines as set forth in the Efficiency Kansas Program Manual.
______ Material or labor costs are NOT paid in advance.
______ No work shall begin until such time as the State Energy Office has approved the appropriate bid and you have been notified in writing.
______ All work will be done in a workman like manner and in accordance with industry standards.
______ For all commercial & industrial projects; if the cumulative amount of all contracts on a project exceeds $2,000 (including but not limited to labor, materials, and equipment) Davis Bacon prevailing wage rates will apply.

• I understand if I am awarded the project that:

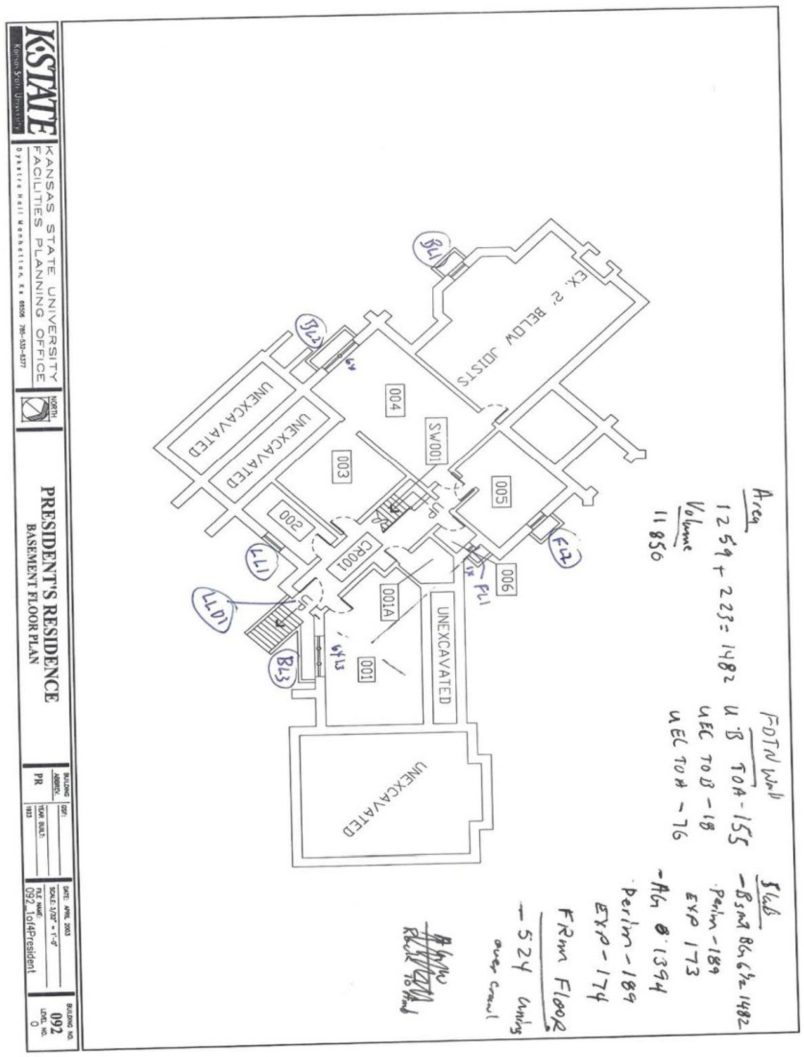
______ I shall only perform those items of work that are approved by the State Energy Office. I shall not perform any extra work requested by the homeowner. If prior approval is not granted, the State Energy Office will not be responsible for the additional costs.
______ Before beginning any home repairs, I will ensure that the customer has been informed as to what materials and supplies will be used and the customer agrees to its content.
______ I will warrant that my work is free from defects in material and workmanship for a period of one (1) year. Upon notice of a material defect in the work within that period, I shall be responsible for any repairs, replacements or corrections to the defective construction within a reasonable period of time, at no cost to the customer. Nevertheless, I shall not be responsible if: (1) my work has been modified, altered, defaced, or had repairs made or attempted by others; or (2) the material defect was caused by an Act of God.

I have read and agree to the terms and conditions of the Efficiency Kansas loan program. I understand that any expenses exceeding what was approved by the State Energy Office, or expenses that exceed the maximum award of the program, will not be the responsibility of the State Energy Office.

__________________________________ ___/___/___
Contractor Signature Date

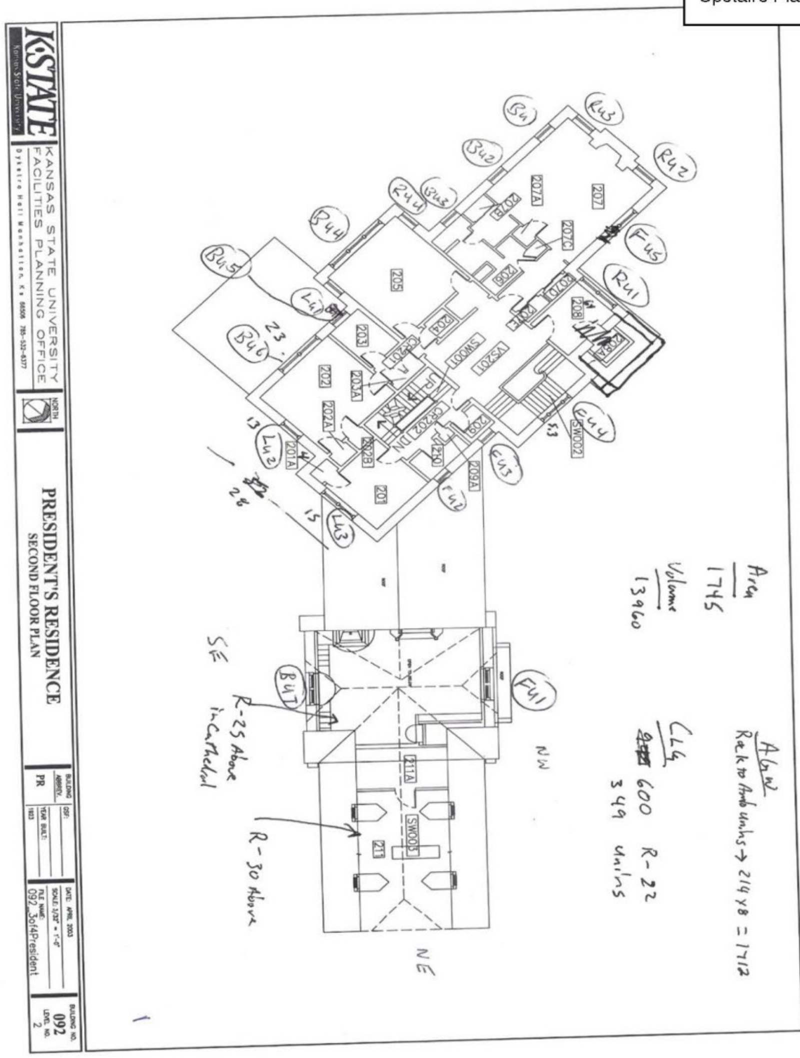


Main Floor Plan



Foundation Plan

Upstairs Plan



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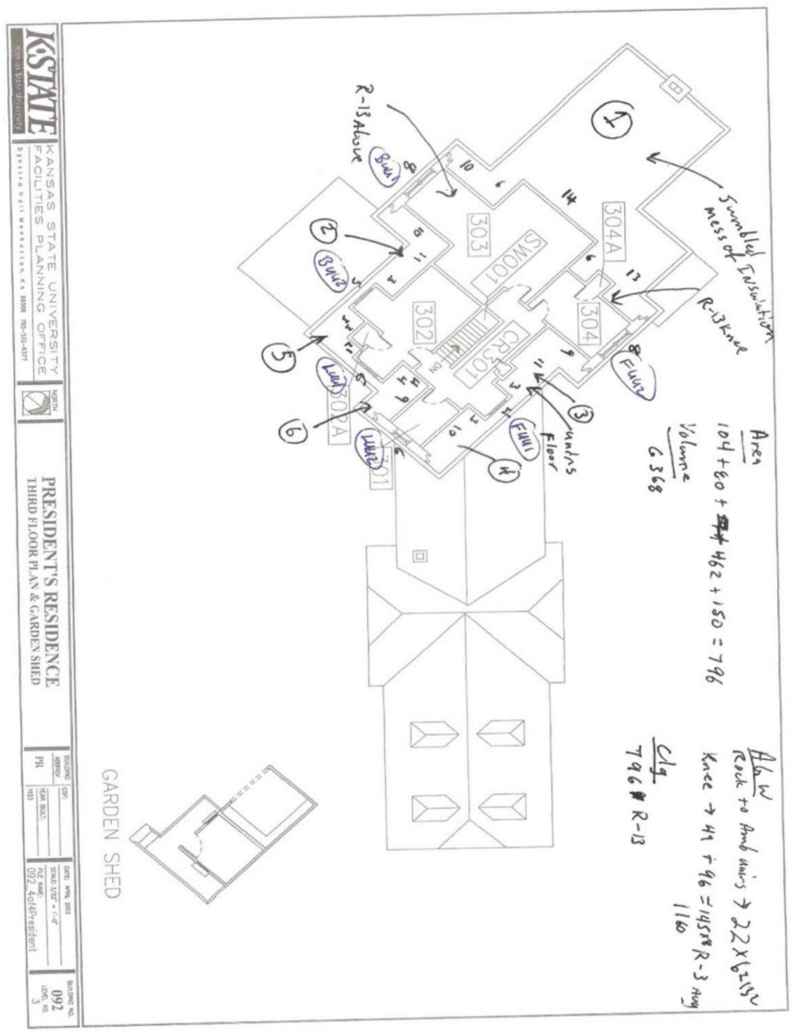

3rd Floor Plan

KSU, Division of Facilities, C/O Casey Lauer, 100 Wilson Ct, Manhattan, KS 66506

Front

KSU, Division of Facilities, C/O Casey Lauer, 100 Wilson Ct, Manhattan, KS 66506



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Air Sealing Action Areas

KSU, Division of Facilities, C/O Casey Lauer, 100 Wilson Ct, Manhattan, KS 66506

The American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) recommends that we have approximately 0.35 air changes per hour in our houses and buildings under normal conditions in order to maintain healthy indoor air quality. However, anything over 0.35 ACH basically leaks our conditioned air back outside, not to mention the extra dust and pests that can come in through the same places air comes in. Specific areas to reduce air infiltration are highlighted below.

Air Tight Home — Leaky Home

Estimated Natural Ventilation Rate in Air Changes per Hour (ACH)

Your Home 1.17

0.25	0.5	0.75	1.0	1.25
Whole-house ventilation recommended or Required; Building Tightness limits without Whole-house ventilation	Carefully Targeted air sealing should produce some energy savings	Moderate air-sealing effort should produce significant savings.	Thorough air-sealing effort should produce impressive energy savings	

Action Area	Description of Work
Exterior walls	Pic 1. Taken in the Attic above the 2nd floor. This pic demonstrates why air is moving through the walls quite easily. Seal this opening with a rigid material sealed to the rock wall and ceiling, or use spray foam to seal the gap that is the top of the wall cavity.
Furnace Room Walls and Ceilings	Pic 2. The walls and ceiling of the furnace room on the 3rd floor are allowing a significant amount of infiltration. Seal joints or remove wall material and replace with drywall. Mud and tape seams.
Kneewall spaces	Pic 3. In the Kneewall spaces (outside the 3rd floor walls), block the floor joists per EKMIM pg 15-16.
Attic and Kneewall access doors	Pic 4-5 Build insulated weather-stripped access doors. See EKMIM pg 5 and 17-18
Chimney Flue	Pic 6. Chimney Damper is open and would not shut easily.
Doors	Pic 7-8. Replace weather stripping. See EKMIM pg 44-48.
Addition	Pic 9-11. Air enters attic through areas as shown in pic 9 (and other places) and passes through the fiberglass insulation to holes in the ceiling as shown in pics 10-11. Seal bookshelf to drywall, especially at the top. See following line for can lights.
Can Lights	Pic 10-11 (5 Total can lights). Build and install boxes to go over can lights in attics (where accessible). Seal box to ceiling. Alternatively, install sealed trim kit or CREE CR6 LED lamp (www.creeledlighting.com), seal trim kit to ceiling and blow insulation at least 3" thick over can lights. Note: Do Not seal or insulate non IC (insulation contact) rated can lights. We recommend replacing non IC cans with IC rated cans.
Crawl space & Rim Joists	Pic 12-13 Although it is more expensive than the other alternatives, high density spray foam applied to rock walls and rim joists is an easy way to create a great air seal and insulate.
Conduit in Bsmt	Pic 14. Seal conduit to prevent air infiltration.

Recommended materials: Foam board, OSB, or other rigid materials for large holes like stud cavities or joist bays. Seal around edges of rigid materials. Great stuff expanding foam for medium size holes like oversized wire penetration holes. Siliconized Acrylic Latex caulking for smaller gaps and cracks (it's paintable). Any brand low or non expanding foam for door and window jambs to prevent bowing of the frames.

See Efficiency Kansas Material and Installation Manual (EKMIM) Pages 2-6 for general guidance on air sealing

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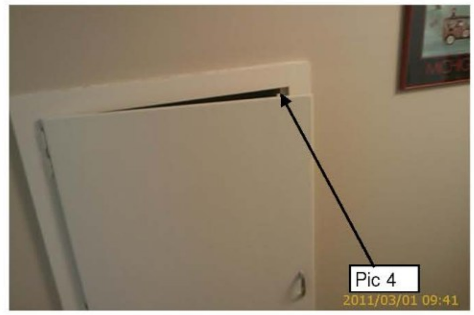

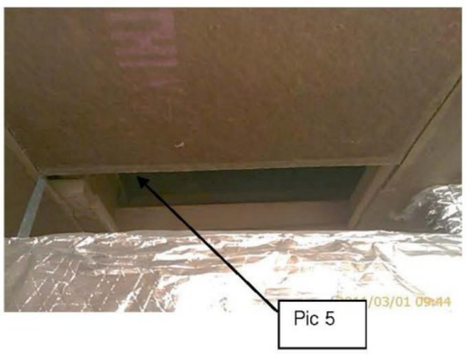

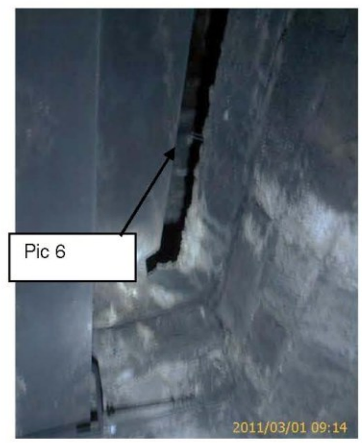

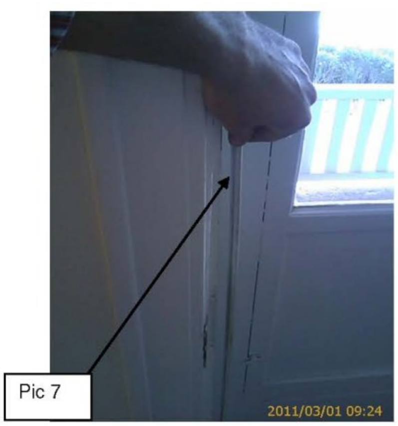

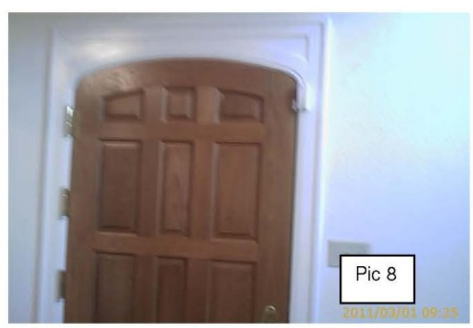

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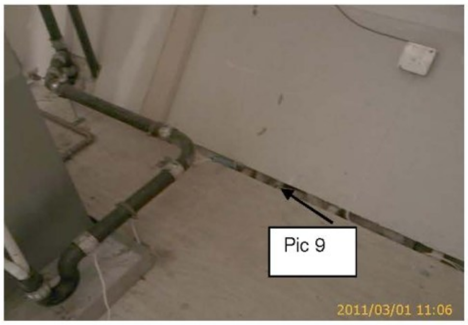

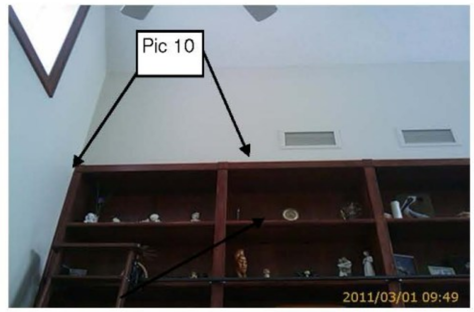

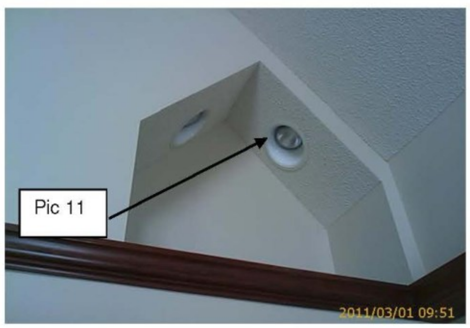

Pic 12

Pic 13

Pic 14

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Equipment Sizing Summary on following page

KSU, Division of Facilities, C/O Casey Lauer, 100 Wilson Ct, Manhattan, KS 66506

The following page is the our modeling software's load calculation. Use it as a guide in sizing heating and air conditioning equipment when a HVAC system is recommended in the energy upgrade table.

Right hand column is heating and air conditioning requirements after energy upgrades. Left hand column represents the current loads and HVAC specifications.

Provides information about heating and cooling to meet the peak loads and the minimum Sensible Heat Fraction (SHF). The sensible cooling capacity of the cooling will be adjusted based on the excess latent capacity of the unit. As a result, the sensible cooling capacity will be increased by 50% of the excess latent cooling capacity.

- Note that the total capacity shown for Heat Pumps includes the Backup Electric Resistive heating, if included in the library's definition for that heat pump.
- Also note that at present, the heating capacity for Air Source Heat Pumps shown in the report is based only on the 47°F capacity, which will be overstated for IECC climate zones 5 and up. A future (as-yet unscheduled) upgrade may estimate the heating capacity at the home's outdoor Design Temperature.

Appendix B - HVAC Load Spreadsheets

Figure B. 1. HVAC Load Using 1.17 ACH Infiltration

Project:		President's Residence									Original
Cooling: Outside db			93	*wb*	75	*Inside db*	75	*RH %*	50	*ΔGrains*	31
Heating: Outside db			-2	*Inside db*	70	*Re: Tbl 4-7A-B*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS	TRANSMISSION	ITEM	EXPOS-URE	AREA	U	U X A	HTG ΔT	TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
		Wall	N	2360	0.25	590.00	72				42480
			N Add.	300	0.06	18.00	72				1296
			S	2360	0.25	590.00	72				42480
			S Add.	300	0.06	18.00	72				1296
			E	1200	0.25	300.00	72				21600
			W	940	0.25	235.00	72				16920
		Glass		968	0.5	484.00	72				34848
		Glass New		80	0.3	24.00	72				1728
		Partitions		112	0.06	6.72	25				168
		Doors		84	0.58	48.72	72				3508
		Ceiling									
	7S,7T	ROOF/CEILING		4185	0.05	209.25	72				15066
		ROOF/CEILING New		480	0.07	33.60	72				2419
		BASEMENT FLOOR		1560	1.7	2652.00	72				2652
		BASEMENT WALL		2400	6.1	14640.00	72				14640
	7V,17	FLOOR		600	1.2	720.00	72				51840
		TRANSMISSION SUBTOTALS									252941
INFILT		5-1, 13A/13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Space CLG		Q_L = CFM x .69 x ΔG		72					
		Space HTG	1255	Q_S = CFM x 1.08 x ΔT		72					97589
		Door CLG				72					
		Door HTG				72					
		INFILTRATION SUBTOTALS									97588.8
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration											**350530**

Figure B. 2. HVAC Load with 0.41 ACH Infiltration

Project:	President's Residence									After Stopping Infiltration
Cooling:	*Outside db*	93	*wb*	75	*Inside db*	75	*RH %*	50	*ΔGrains*	31
Heating:	*Outside db*	-2	*Inside db*	70	*Re: Tbl 4-7A-B*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS / TRANSMISSION	ITEM	EXPOS-URE	AREA	U	U X A	HTG ΔT	TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N	2360	0.25	590.00	72				42480
		N Add.	300	0.06	18.00	72				1296
		S	2360	0.25	590.00	72				42480
		S Add.	300	0.06	18.00	72				1296
		E	1200	0.25	300.00	72				21600
		W	940	0.25	235.00	72				16920
	Glass		968	0.5	484.00	72				34848
	Glass New		80	0.3	24.00	72				1728
	Partitions		112	0.06	6.72	25				168
	Doors		84	0.58	48.72	72				3508
	Ceiling									
7S,7T	ROOF/CEILING		4185	0.05	209.25	72				15066
	ROOF/CEILING New		480	0.07	33.60	72				2419
	BASEMENT FLOOR		1560	1.7	2652.00	72				2652
	BASEMENT WALL		2400	6.1	14640.00	72				14640
7V,17	FLOOR		600	1.2	720.00	72				51840
							TRANSMISSION SUBTOTALS			252941
INFILT	5-1, 13A/13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG		Q_L = CFM x .69 x ΔG		72					
	Space HTG	440	Q_S = CFM x 1.08 x ΔT		72					34214
	Door CLG				72					
	Door HTG				72					
							INFILTRATION SUBTOTALS			34214.4
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration										**287155**

Figure B. 3. HVAC Load with Window Film

Project:		President's Residence									After Installing Window Film
Cooling:		*Outside db*	93	*wb*	75	*Inside db*	75	*RH %*	50	*ΔGrains*	31
Heating:		*Outside db*	-2	*Inside db*	70	*Re: Tbl 4-7A-B*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS	TRANSMISSION	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
		Wall	N	2360	0.25	590.00	72				42480
			N Add.	300	0.06	18.00	72				1296
			S	2360	0.25	590.00	72				42480
			S Add.	300	0.06	18.00	72				1296
			E	1200	0.25	300.00	72				21600
			W	940	0.25	235.00	72				16920
		Glass		968	0.311	301.05	72				21675
		Glass New		80	0.3	24.00	72				1728
		Partitions		112	0.06	6.72	25				168
		Doors		84	0.58	48.72	72				3508
		Ceiling									
	7S,7T	ROOF/CEILING		4185	0.05	209.25	72				15066
		ROOF/CEILING New		480	0.07	33.60	72				2419
		BASEMENT FLOOR		1560	1.7	2652.00	72				2652
		BASEMENT WALL		2400	6.1	14640.00	72				14640
	7V,17	FLOOR		600	1.2	720.00	72				51840
								TRANSMISSION SUBTOTALS			239768
INFILT		5-1, 13A/13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Space CLG		Q_L = CFM x .69 x ΔG		72					
		Space HTG	1255	Q_S = CFM x 1.08 x ΔT		72					97589
		Door CLG				72					
		Door HTG				72					
						INFILTRATION SUBTOTALS					97588.8
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration											**337357**

Figure B. 4. HVAC Load with Window Film and 0.41 Infiltration

Project:	President's Residence									After Stopping Infiltration and Installing Window Film
Cooling:	*Outside db*	93	*wb*	75	*Inside db*	75	*RH %*	50	*ΔGrains*	31
Heating:	*Outside db*	-2	*Inside db*	70	*Re: Tbl 4-7A-B*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS / TRANSMISSION	ITEM	EXPOS-URE	AREA	U	U X A	HTG ΔT	TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N	2360	0.25	590.00	72				42480
		N Add.	300	0.06	18.00	72				1296
		S	2360	0.25	590.00	72				42480
		S Add.	300	0.06	18.00	72				1296
		E	1200	0.25	300.00	72				21600
		W	940	0.25	235.00	72				16920
	Glass		968	0.311	301.05	72				21675
	Glass New		80	0.3	24.00	72				1728
	Partitions		112	0.06	6.72	25				168
	Doors		84	0.58	48.72	72				3508
	Ceiling									
7S,7T	ROOF/CEILING		4185	0.05	209.25	72				15066
	ROOF/CEILING New		480	0.07	33.60	72				2419
	BASEMENT FLOOR		1560	1.7	2652.00	72				2652
	BASEMENT WALL		2400	6.1	14640.00	72				14640
7V,17	FLOOR		600	1.2	720.00	72				51840
						TRANSMISSION SUBTOTALS				239768
INFILT	5-1, 13A/13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG		Q_L = CFM x .69 x ΔG		72					
	Space HTG	440	Q_S = CFM x 1.08 x ΔT		72					34214
	Door CLG				72					
	Door HTG				72					
					INFILTRATION SUBTOTALS					34214.4
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration										**273983**

Appendix C - Degree Day Spreadsheets

Figure C. 1. Degree Day Calculations with ACH Infiltration

Degree Days

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
q_L Before	350530	350530	350530	350530	350530	350530	350530	350530	350530	350530	350530	350530
q_L After Stop Infil.	287155	287155	287155	287155	287155	287155	287155	287155	287155	287155	287155	287155
q_L After Window Film	337357	337357	337357	337357	337357	337357	337357	337357	337357	337357	337357	337357
q_L After Both	273983	273983	273983	273983	273983	273983	273983	273983	273983	273983	273983	273983
Manhattan, KS DD	1153	864	637	315	106	7	0	4	48	265	697	1042
η	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
HV	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050
ΔT	72	72	72	72	72	72	72	72	72	72	72	72
Cd	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77

MCF Before	109.77	82.26	60.65	29.99	10.09	0.67	0.00	0.38	4.57	25.23	66.36	99.20
MCF After Stop Infil.	89.93	67.39	49.68	24.57	8.27	0.55	0.00	0.31	3.74	20.67	54.36	81.27
MCF After Wind. Film	105.65	79.17	58.37	28.86	9.71	0.64	0.00	0.37	4.40	24.28	63.86	95.48
MCF After Both	85.80	64.29	47.40	23.44	7.89	0.52	0.00	0.30	3.57	19.72	51.87	77.54

Item	Value	Units
Efficiency	80	%
Gas Heating Value	1050	BTH/cf
Design ΔT	72	°F
$/MCF	$9.50	

	Total MCF	$/Year
Before	489.17	$ 4,647.08
After S.I.	400.73	$ 3,806.90
After WF	470.78	$ 4,472.45
After B	382.34	$ 3,632.28

Note: Manhattan, KS Degree Days information obtained from noaa.gov

Appendix D - Light Survey

Figure D. 1. Lamp Survey Basement and First Floor

	Fixture Type	# Fixt.	# Lamps/ Fixt.	Watts/ Lamp	Lamp Type	Total Watts	New Watts/Fixt	New Total Watts	Watt Savings	Hrs of Op/Day	KWH Before	KWH After	KWH Savings
Basment													
Hall	Light	3	1	23	CFL	69	-	-	-	4	100.74	-	-
Treadmill	Light	1	1	23	CFL	23	-	-	-	4	33.58	-	-
Bathroom	Light	1	1	23	CFL	23	-	-	-	1	8.395	-	-
Living Room	Recessed	4	2	32	Fluor.	256	-	-	-	4	373.76	-	-
	Light	3	2	100	Incand.	600	23	138	462	4	876	201.48	674.52
	Lamp	1	1	15	CFL	15	-	-	-	1	5.475	-	-
Mech Room	Exposed	3	1	23	CFL	69	-	-	-	0.1	2.5185	-	-
Storage	Light	3	1	23	CFL	69	-	-	-	0.1	2.5185	-	-
Kitchen	Recessed	4	2	32	Fluor.	256	-	-	-	4	373.76	-	-
	Recessed	2	2	17	Fluor.	68	-	-	-	4	99.28	-	-
	Light	1	1	23	CFL	23	-	-	-	4	33.58	-	-
First Floor													
Reception Hall	Sconce	2	1	25	Incand.	50	23	46	4	12	219	201.48	17.52
	Chandelier	1	3	100	Incand.	300	26	78	222	12	1314	341.64	972.36
Living Room	Lamp	1	4	75	Incand.	300	23	92	208	8	876	268.64	607.36
	Lamp	1	1	150	Incand.	150	23	23	127	8	438	67.16	370.84
	Lamp	2	2	100	Incand.	400	23	92	308	8	1168	268.64	899.36
	Lamp	1	1	150	Incand.	150	23	23	127	8	438	67.16	370.84
	Lamp	1	1	100	Incand.	100	23	23	77	8	292	67.16	224.84
	Lamp	1	1	23	Incand.	23	-	-	-	8	67.16	-	-
Sun Parlor	Chandelier	1	3	100	Incand.	300	26	78	222	12	1314	341.64	972.36
Dining Room	Chandelier	1	8	100	Incand.	800	23	184	616	8	2336	537.28	1798.72
Rear Hall	Light	2	1	23	CFL	46	-	-	-	12	201.48	-	-
Bathroom	Light	1	2	23	CFL	46	-	-	-	1	16.79	-	-
	Sconce	2	2	40	Incand.	160	23	92	68	1	58.4	33.58	24.82
Kitchen	Recessed	2	2	32	Fluor.	128	-	-	-	12	560.64	-	-
	Recessed	1	1	32	Fluor.	32	-	-	-	12	140.16	-	-
Eat in Kitchen	In Beam	1	9	32	Fluor.	288	-	-	-	12	1261.44	-	-
	Chandelier	1	1	100	Incand.	100	100	100	0	8	292	292	0
Living Room	Track	1	8	100	PAR	800	30	240	560	6	1752	525.6	1226.4
	Fan	3	1	23	CFL	69	-	-	-	6	151.11	-	-
	Cove	2	1	100	PAR	200	30	60	140	6	438	131.4	306.6
	Lamp	1	1	23	CFL	23	-	-	-	4	33.58	-	-
	Lamp	1	1	100	Incand.	100	23	23	77	4	146	33.58	112.42
	Cove	2	1	100	PAR	200	30	60	140	6	438	131.4	306.6
Garage	Cove	1	1	100	PAR	100	30	30	70	2	73	21.9	51.1
	Exposed	2	1	23	CFL	46	-	-	-	1	16.79	-	-
	Exposed	2	1	23	CFL	46	-	-	-	1	16.79	-	-

Figure D. 2. Lamp Survey Second and Third Floor

	Fixture Type	# Fixt.	# Lamps/ Fixt.	Watts/ Lamp	Lamp Type	Total Watts	New Watts/Fixt	New Total Watts	Watt Savings	Hrs of Op/Day	KWH Before	KWH After	KWH Savings
Second Floor													
Upper Hall	Light	1	3	100	Incand.	300	23	69	231	12	1314	302.22	1011.78
	Lamp	1	1	9	CFL	9	-	-	-	4	13.14	-	-
Guest Room A	Lamp	1	1	15	CFL	15	-	-	-	1	5.475	-	-
	Light	2	1	15	CFL	30	-	-	-	2	21.9	-	-
	Light	1	1	32	Fluor.	32	-	-	-	0.1	1.168	-	-
Master Bedroom	Light	5	1	23	CFL	115	-	-	-	4	167.9	-	-
	Light	2	1	15	CFL	30	-	-	-	4	43.8	-	-
	Lamp	1	1	23	CFL	23	-	-	-	4	33.58	-	-
	Fan	1	3	23	CFL	69	-	-	-	4	100.74	-	-
Master Bathroom	Light	5	1	15	CFL	75	-	-	-	2	54.75	-	-
	Light	6	1	23	CFL	138	-	-	-	2	100.74	-	-
Guest Room B	Light	2	1	100	Incand.	200	23	46	154	6	438	100.74	337.26
	Light	1	1	23	CFL	23	-	-	-	6	50.37	-	-
Bathroom	Light	2	1	23	CFL	46	-	-	-	2	33.58	-	-
Guest Room C	Lamp	2	1	15	CFL	30	-	-	-	2	21.9	-	-
	Light	2	1	100	Incand.	200	23	46	154	4	292	67.16	224.84
Upper Rear Hall	Light	1	1	15	CFL	15	-	-	-	6	32.85	-	-
Guest Room D	Lamp	2	1	15	CFL	30	-	-	-	4	43.8	-	-
Bathroom	Sconce	2	1	15	CFL	30	-	-	-	1	10.95	-	-
	Light	1	1	23	CFL	23	-	-	-	1	8.395	-	-
Third Floor													
Bed Room	Lamp	1	1	23	CFL	23	-	-	-	1	8.395	-	-
	Light	1	1	15	CFL	15	-	-	-	2	10.95	-	-
	Light	2	1	100	Incand.	200	23	46	154	2	146	33.58	112.42
Mech Room	Recessed	5	2	32	Fluor.	320	-	-	-	0.1	11.68	-	-
	Exposed	1	1	23	CFL	23	-	-	-	0.1	0.8395	-	-
Guest Room	Lamp	2	1	23	CFL	46	-	-	-	2	33.58	-	-
	Light	2	1	23	CFL	46	-	-	-	2	33.58	-	-
Hall	Light	2	1	23	CFL	46	-	-	-	4	67.16	-	-
Bathroom	Light	1	1	23	CFL	23	-	-	-	1	8.395	-	-
	Exposed	1	6	60	Incand.	360	23	138	222	1	131.4	50.37	81.03
								Total Watt Savings	4343				
											Total KWH Savings		10703.99
											Total $ Savings/Year		$1,177.44

Appendix E - EnergyStar U-Factor Zones

ENERGY STAR® Qualification Criteria for Residential Windows, Doors, and Skylights

Windows

Climate Zone	U-Factor[1]	SHGC[2]	
Northern	≤ 0.30	Any	Prescriptive
	–0.31	≥ 0.35	Equivalent Energy Performance
	–0.32	≥ 0.40	
North-Central	≤ 0.32	≤ 0.40	
South-Central	≤ 0.35	≤ 0.30	
Southern	≤ 0.60	≤ 0.27	

Doors

Glazing Level	U-Factor[1]	SHGC[2]
Opaque	≤ 0.21	No Rating
≤ ½-Lite	≤ 0.27	≤ 0.30
> ½-Lite	≤ 0.32	≤ 0.30

Skylights

Climate Zone	U-Factor[1]	SHGC[2]
Northern	≤ 0.55	Any
North-Central	≤ 0.55	≤ 0.40
South-Central	≤ 0.57	≤ 0.30
Southern	≤ 0.70	≤ 0.30

[1] Btu/h.ft^2.°F

[2] Fraction of incident solar radiation