ENERGY EFFICIENCY MEASURES FOR SINGLE FAMILY HOUSING IN FLORIDA

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
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To my wife and family whose unyielding love and support is a constant that I can always rely on

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Over recent history the sustainability movement has grown by leaps and bounds. Sustainability was once limited to specialized higher level theory but has recently moved into the public mainstream. Fueled by growing social awareness of climate change and the financial benefits, residential home owners are looking to “go green” and reduce their energy consumption. Home owners are however at a disadvantage as they are generally not well educated on the specifics of energy conservation. When they attempt to find information on how to reduce their energy use they are bombarded with vendors peddling products however the solid data on how effective the measures are can be very illusive. Critical unanswered question on cost, efficiency and return on investment keeps many home owners from acting on their initial intentions. What is worse is many home owners do not know that energy efficiency measures are not consistent throughout the country. Measures that save energy in Florida may actually draw more energy in Wisconsin. Energy efficiency measures are very specific to geographic region and building types. To address this problem this research will take common energy efficiency measures and test them on a computer simulated model of a typical Florida house. The characteristics of the house will be based on actual data collected from Florida housing surveys and represent features common to more than 50% of all Florida houses. The model house will be constructed on a 3D computer modeling platform to ensure the accuracy of the

energy and cost estimates. Energy modeling software will be used to calculate the effectiveness of the measures. Once completed a matrix that includes initial capital cost, effectiveness measured in cost per year, and pay back durations based on current finance rates will be created. Home owners can use the matrix and extrapolate the effectiveness and pay back of each of the common measures on their specific residence. As the model house consists of characteristics most common to Florida houses the energy savings should closely mirror the individual home owner's situation. The residential housing market consumes nearly 40% of all of America's electrical energy. Providing residential home owners the tools to make informed energy reduction decisions is low hanging fruit that should not be ignored.

CHAPTER 1
INTRODUCTION

Background

Over the past 30 years the general public as a whole has become very sensitive to the growing amount of energy that the built environment consumes. Because of the obvious advantages of energy conservation, like lower costs and greater environmental responsibilities, the public is willing to make changes in its lifestyle and invest in capital improvements to enjoy these benefits. However the residential market is a vastly underutilized area for energy conservation. According to the Department of Energy, residential buildings consume approximately 38% of the total U.S. electrical energy. While there have been many improvements with how new homes are built, this only represents a small fraction of the total residential building stock. The Department of Energy also reports that there are approximately 116 million existing homes with only 500,000 - 2,000,000 built every year. Clearly the segment within the residential market that has the most opportunity for improvement is in retrofitting existing homes and making them more efficient.

Statement of Purpose

Despite the desire to reduce their energy consumption critical unanswered question of cost, efficiency and return on investment keeps many home owners from acting on their initial intentions. As a group, home owner are not well educated on the specifics of conservation techniques, energy modeling, or construction cost. These areas are the pillars that this study is built on. The question of “What energy efficiency measures (EEMs) are effective at reducing residential energy consumption?” is the central question that this research seeks to answer.

Objective

This study looks to identify effective means of reducing residential energy consumption however it is critical to put the word “effective” in the proper context. For the purpose of this research effectiveness will be framed in terms of energy reduced from normal and initial influx of capital expense. Another way of phrasing this is the inverse relationship of energy saved verse capital cost.

The first key component of effectiveness is the calculation of energy saved. To this end a computer simulated model house was created and served as the baseline to which each EEM was compared. Inputs like insulation values, HVAC equipment, window area, and other energy influencing factors were entered into an energy modeling computer program and an average energy consumption value was calculated. With the baseline established each EEM was then entered into the energy model and the saving calculated.

The second key component of effectiveness is the estimating of initial cost required to implement the EEMs. To accomplish this published construction cost data in combination with estimating software programs were used to create detailed estimates. The estimates were itemized to include factors like labor, material cost, permitting fees, taxes, delivery charges, general conditions and overhead & profit. Estimates were verified for accuracy by comparing actual market prices from real world vendors of similar products.

Limitations of Research

Within the built environment there are many different building types and climates that have specific qualities which may vary the effectiveness of each EEM. The first limitation of the study is geographical. This research reviewed the hot/humid climate type specifically within the state of Florida. The second limitation is the type of residential housing units reviewed. The study ignores all multifamily structures, rental units, attached structures, and manufactured housing but focuses solely on single family detached houses. The third limitation of the study is on the type of EEMs tested. There are many EEM available however this study tests only well established residential EEMs. These measures are largely those endorsed by established experts in the fields of building energy use like the U.S. Department of Energy, U.S. Green Building Council and the Energy Star ™ program.

CHAPTER 2
LITERATURE REVIEW

Overview

In this age of growing awareness of the Earth's limited energy reserves and environmental consequences of power generation, the topic of Energy Efficiency Measures (EEMs) has been greatly discussed. While there are many entities that place demands on the world's energy market such as manufacturing, transportation and commerce in the United States, one of the heaviest energy using segments is the residential housing market. According to the Department of Energy (2010), residential housing uses 38% of the total electrical energy produced. With residential housing being such a large consumer of energy, measures that create even a small reduction by percentage will produce a significant reduction of the total national demand. In this literature review the current state of knowledge of what EEMs are available for Florida housing and how specific climates dictate which EEMs are effective will be reviewed.

Energy Efficiency Measures Available

The sustainability movement in the United States has made great strides over the past 15 years. As energy conservation is a key component of this movement a great deal of research has been done on identifying how energy is used and developing measures on how to reduce the demand. However, to get the most return on the investment it is important to focus on the areas of a home that consume the most energy. According to the Department of Energy, on average Americans use two and half times more energy on space heating than on home electronics (See Figure 2-1). Purchasing a more expensive but energy efficient television may yield the same or even less energy savings than if the money were used for a programmable thermostat. EEMs are often categorized into five groupings which will be mirrored in this research:

- Space Conditioning
- Water Heating

- Building Envelope
- Lighting, Appliances, Miscellaneous Electrical Loads
- Home Energy Management

In this chapter various specific measures typical to the hot/humid climate type will be grouped into these same categories and explored in detail.

Space Conditioning

Ceiling fans

Ceiling fans originated in the United States dating back to the mid ninetieth century. Originally they were not powered by electric motors but by streams of water that would usually power several fans in series and were commonly seen in offices, restaurants and stores. The electric power fan is largely credited to Philip Diehl who introduced the Diehl electric fan in 1882. Ceiling fans remained popular in the United States until the 1930s when their popularity rapidly declined. It was not until the 1970s when they started to become more in vogue (Scharff 1983).

Ceiling fans can provide a low cost means of energy reduction when used in tandem with a home's HVAC system. A ceiling fan moves air which increases the evaporation rate of moisture on the skin causing people to feel cooler at higher temperatures. This cooling effect allows for people to increase the temperature on their thermostats by 3 or 4 degrees and feel just as comfortable. Ceiling fans can also be used in the winter months. Most modern fans have an option to reverse the direction the blades turn. While air flow in the winter months may still increase evaporation and thus the chill effect, reversed fans can also pull warm air from the ceiling and push it down into the living space (Progress Energy 2010).

HVAC tune-up

Similar to automobiles or any other piece of mechanical equipment HVAC systems need regular maintenance to operate properly. According to a publication made by Energy Star ™

(Energy Star 2009), “dirt and neglect are the top causes for heating and cooling systems inefficiencies and failure”. Energy Star ™ recommends that each of the following maintenance items be addressed regularly either by the home owner or a qualified service person.

- Check the thermostat so that it turns on and off at the set point. If a programmable thermostat is used verify that the program is accurate for the occupancy lifestyle.
- Verify all electrical connections especially those to the motor are tight and adequately secured.
- Lubricate moving parts.
- Check to make sure that the condenser line is clear. This will not save energy however a clogged condenser line can cause significant water damage to a home.
- Check the condenser operation to make sure it has a proper start up and shut down.
- Check and clean the filter regularly but never longer than 3 months.
- Clean indoor and outdoor coils.
- Clean blower fan (see Figure 2-2).
- Check the charge of the refrigerant. Too much or too little can diminish the performance of the equipment.
- Make sure the blower is free from obstructions and debris.

Sealing leaking HVAC ductwork

Leaking ductwork is one of the largest contributors to residential HVAC equipment inefficiency. According to the Department of Energy, the average house looses 20% of their conditioned air through leaking or kinked ductwork (US DOE 2009). Some of the areas that contribute the most to the issue are flexible ductwork that is kinked and restricting flow, poorly connected ducts to registers, leaky or torn ductwork especially at connections and inadequately sealed air handlers. Residential HVAC systems are especially susceptible to leaking ductwork because of the heavy use of duct tape. Despite its seaming unending list of applications, it actually seals ducts very poorly. Over time duct tape loses adhesion and falls apart. The deterioration is accelerated in extreme temperatures commonly found in attics and unconditioned crawl spaces. Repairing the problem can be relatively easy is some areas but also very invasive in others. For instance, resealing air handlers, ductwork, and register connections can be completed easily with minimal cost by homeowners as long as they have proper access. However, ductwork and connections may be in wall cavities or attics that are not easily accessible making resealing them difficult. Despite the mixed bag of difficulties, pursuing duct leak mitigation can yield some significant benefits. According to the California Energy Commission, providing retrofit repairs to leaking ductwork in residential homes can typically increase HVAC efficiency by 10% or more (US DOE 2009).

High SEER HVAC units

When measuring the efficiency of a home's HVAC system the unit's seasonal energy efficiency ratio (SEER) is usually what is considered. The SEER rating is calculated by dividing the cooling output during the cooling season by the energy used during this same period. The units used are BTUs divided by watts per hour. A unit's energy efficiency ratio (EER) is similar to the SEER however EER is for total year conditions and SEER is only for the cooling season. The EER is usually less than the SEER and for most residential HVAC units a factor of .875 can be applied to the SEER to convert it to the EER (Air Conditioning, Heating and Refrigeration Institute 2008).

Starting in 2006, the U.S. government required that all new HVAC units have a minimum SEER rating of 13. Older units were often found to have SEERs of nine however the number of these units are dwindling as the aging units are replaced (Norland 2006). More progressive owners who wish for higher efficient units can choose Energy Star ™ systems that have a minimum SEER of 14 (US DOE 2011). Some manufacturers offer super efficient units with

SEERs of 16 to 23 however they are at a significantly higher cost than comparable 13 SEER units (Consumer Search 2011).

Water Heating

Low flow shower heads and aerators

It may not be intuitive to think how the reduction in water use will increase a home's energy efficiency. However, if you consider that most residential homes have a tank style water heater that uses electricity to heat water than the reduction in water use makes sense. According to the Shimberg Center for Affordable Housing the median year built for Florida single family houses is 1988. This is an important date as it precedes the Water Resources Development Act of 1992. This act put some aggressive restriction on water use for most new residential plumbing fixtures. For example, the act limits the water use of shower heads to 2.5gpm at 80psi where before 1992 some shower heads had a flow rate of 5.5gpm. Showering represent about 20% of the total residential water use and presents a good opportunity to reduce overall demand. Fortunately, retrofitting existing homes with new low flow shower heads is relatively simple and cost effective. The use of aerators is another way to reduce hot water use. These devices will not actually restrict the use of water from a faucet (although models can be purchased that do this as well) however they effectively mix air and water. This mixture of air and water more efficiently allows for solids to be dissolved in water and washed off. Essentially, using aerated water allows for dishes or any other object to be washed quicker with less water. Showers and faucets constitute over 43% of all residential water use so implementing measures to reduce consumption in these two areas can provide a significant return on investment (Vickers 2001).

Solar water heaters

The use of solar energy to heat water is not a new concept. The history of solar water heating dates back to sketches from Leonardo da Vinci, with improvements during the industrial revolution and introduction into the U.S. mainstream after the 1973 Arabian oil embargo. Modern solar heated water systems are divided into three basic types; low, medium and high temperature systems. Low temperature systems heat water to a maximum of 110 degrees and are by far the most common. The popularity of these units is due to their effectiveness with residential pools. These solar pool heaters generally use a black flexible mat with integrated tubing as a collector of the solar energy. Water is circulated from the pool, into the collector and then back into the pool. Often times a photovoltaic panel is used to power the pump. Photovoltaic powered pumps are ideally suited for this situation as when there is an abundance of solar energy the pump will circulate the highest amount of water and maximize the heat transferred into the pool. However, on cooler overcast days the pump will not circulate as much water and help avoid the pool loosing heat through the collector. The second type of water heater is the medium temperature system and heats water between 110 and 180 degrees. Domestic solar heated water systems are generally medium temperature types. One common medium temperature design is the integrated storage unit type. This design uses several large diameter copper tubes set in an insulated five sided box with a glass lid. The insulated box collects the solar energy and transfers the heat through the copper tube walls. The insulated box is usually mounted at the roof level and uses municipal water pressure and gravity to provide the necessary water pressure. Another type of medium temperature systems uses a similar insulated box but circulates water through small copper tubes from the box into a storage tank. This type of system is more common as it is less susceptible to leaks, allows for a conventional heating coil as back up and easier to retrofit into existing residence. High temperature systems are not used residentially and most commonly used for power generation. The system uses parabolic troughs to concentrate solar energy and super heat water to steam. This super heated steam, heated to temperatures near 1,450 degrees in some cases, is used to turn turbines to produce electrical energy (Wilson 1999).

Building Envelope

Window films

Windows influence the energy consumption of a home more than any other exterior feature. It is estimated that windows account for 15 – 30% of the winter heating load and over half of the summertime cooling load. Researchers at the Lawrence Berkley National Laboratory estimate that residential windows account for 3.2% of the total United States annual energy consumption and 9% of all residential energy consumption. There are many factors that influence the efficiency of a window such as frame material, layers of glass, air spaces, and insulation to name a few. Most of these measures are not easily retrofitted to existing windows however. One exception to this is the use of externally applied window film. These window films are thin plastic sheets applied on the interior side of the glass (Wilson 1996).

There are two basic types of window films. The first is a dye-tinted film which blocks solar heat gain through the absorption of both visible light and solar radiated heat. The dye-tinted films have been available for retrofit application since the late 1960s but have not gained much traction with the residential market. This is primarily because home owners are unwilling to substitute low natural light for reduced solar heat gain. The second type of film is light spectrum selective and relies on reflectivity and emissivity. These films block the longer infrared and UV light waves, responsible for almost half of the solar heat gain, but still allows most of the shorter visible light waves through. There are many film manufacturers with varying claims of efficiency however on their website 3M stated that their Prestige line of window films allows the owner to enjoy a reduction of 60% of heat gain with only a 30% reduction in light emissions (Environmental Building News 2010).

Insulation

The exterior of a home is called its shell or envelope and is the point of separation between the outside elements and conditioned space. The envelope however can have many penetrations making it a less effective barrier. Energy Star ™ reports that home owners can easily decrease the load on their HVAC systems by 20% by properly insulating their home. Adding insulation in the attic floor is one of the easiest and most effective ways a home owner can tighten up their homes envelop. The recommended insulation in the attic is R-38 which is between 12 and 15 inches. Adding rigid or spray foam insulation at the roof deck is another way of protecting the home's envelope. Adding insulation at the roof deck has the advantage of moving the barrier further away from conditioned space. Locating and sealing penetrations in the walls is another energy efficiency measure. Detecting air penetrations in the wall can be difficult and may require the services of a professional with inferred cameras and specialty instruments. However, once they are located spray foams can be used to seal the penetrations with minimal finish rework (Energy Star 2009).

Low E glass

Low Emissivity glass commonly called Low-E glass is specially formulated glass designed to increase the energy performance of the window. The U.S. Department of Energy states that "Low-E coatings typically cost about 10%–15% more than regular windows, but they reduce energy loss by as much as 30%–50%". What makes glass Low-E is an extremely thin metal or metallic oxide layer placed on the warm side of the glass. The Low-E layer reduces the inferred heat transference from the sun's rays. Older Low-E coating also diminished the amount of visible light transferred through the glass however with the development of spectrally selective coatings the light transmitted is virtually the same as traditional glass. In addition to Low-E glass, many other improvements have been made to modern windows. One of these advances is the use of thermal breaks in the window frame. This reduces the heat transference through the window frame. Another development in window efficiency is the use of double paned insulated glass. This glass has an air space which retards the flow of convection and conduction heat through the glass. In some high efficiency window systems argon gas is used instead of normal nitrogen heavy air as a means of additional heat transmission reduction (US Department of Energy 2010).

Light tubes / skylights

While the use of light tubes has gained some recent public interest it is not a new technology. Rudimentary light tubes have been used aboard ships for centuries. A light tube system consist of a transparent aperture on a roof that "catches" the light, a reflective light channel or tube that transports the light and a diffuser which disperses the light into occupied space. Light tubes are primarily used in residential applications and the tube ranges in size from 8" to 24". The tubes are made of highly reflective material to minimize the light absorbed and thus lost in transport. Skylights are another means of importing natural lights into a building. Skylights are essentially windows on the roof. In years past skylights were used for beatification but caused a net increase in power consumption. They provided natural lighting however the increased solar heat gains created added demand on a buildings HVAC system. Today, with the use of double paned high efficiency glass the heat gain has been significantly reduced making them a source of beauty and energy efficiency (Wilson 1999).

Lighting, Appliances, Miscellaneous Electrical Loads

Compact fluorescent lights

When replacing light bulbs throughout the house many consumers think that the wattage indicated on the bulb is a measure of how bright the bulb is. While there can be truth in this, what is not always thought of is that the watt is actually a measure of the rate of energy conversion or stated another way is one joule of energy over one second of time. As a watt is a measure of conversion, the higher the wattage of a light bulb the higher the conversion of electrical energy to light. In residential homes the incandescent light is traditionally what is used for creating artificial light. The incandescent light bulb is century old technology widely accredited to Thomas Edison although there were 22 individual inventors of different incandescent lamps prior to Edison (Friedel and Israel 1986). The common incandescent light bulb passes current through a filament heating it until it produces visible light. According to General Electric (1964) over 90% of the energy used in an incandescent light bulb is used to generate heat. This heat is not just wasted energy but puts additional load on a home's HVAC system. With the obvious disadvantages to the common incandescent lights some consumers have demanded a better option for their home lighting needs. The introduction of the compact fluorescent light (CFL) offers an opportunity for a significant reduction in energy use which many consumers are finding desirable.

The mechanics of compact fluorescents are, as its name suggests, the same as a traditional fluorescent lamp. The lamp is a glass cylinder in which an electrical charge is used to excite mercury vapors which produces visible light. CFLs are compatible with devices that use traditional incandescent light bulbs. The CFL bulb simply screws into a standard light socket just as an incandescent bulb does. The most common types of CFL are the straight tube and the spiral tube type. The straight tube type has a slightly higher efficiency than the spiral type as the spiral type requires a thicker glass wall to support the curved glass. For either type of CFL the efficiency is significantly higher than that of incandescent lamps. On average CFL uses 75% less energy than a comparable incandescent lamp. According to a publication by Energy Star ™ if every home in America were to switch only one of their incandescent lamps to a CFL it would “save enough energy to light 3 million homes for a year, save about $600 million in annual energy costs, and prevent 9 billion pounds of greenhouse gas emissions per year, equivalent to those from about 800,000 cars”.

Despite the significant energy savings advantages, CFLs represent a small fraction of the lighting market share and it appears to be in a state of decline. In 2009 it was estimated that only 11% of available light sockets were filled with CFL (Vessel 2009). Richard Karney, Energy Star’s ™ CFL production manager indicated that sales of CFLs have reduced by 25% from their peak in 2007 to 2009. “The market for CFLs is far from transformed,” Karney said. “Based on additional data and analysis that DOE has continued to gather, it’s apparent that the market is headed in the wrong direction.” This direction could be linked to two major issues that CFLs have to contend with. First, CFL use mercury gas to produce light. Consumers are particularly sensitive to mercury levels in food products and concerned about mercury gas in their homes if a bulb were to break. The second issue that may be limiting CFL acceptance by the public is that the initial cost is significantly higher than a comparable incandescent light. The paybacks are decisively documented however if a CFL were damaged and needed to be replaced the proforma would change. It is important to note however that CFLs have significantly longer life spans than incandescent options which could also be affecting the sales figures.

The argument about whether CFL producers can win over consumers has largely become moot in recent years. In the early part of the decade several states which include California, Connecticut and New Jersey passed legislation restricting the sale of traditional low efficiency lamp. The unquestionable biggest push forward for CFL came from the Federal government with the passing of the Energy Independence and Security Act of 2007. This act calls for a 30% improvement in efficiency from the traditional incandescent bulb starting in 2012 through 2014.

The program starts with lamps of 100 Watts in 2012 and move to 40 Watts bulbs in 2014. Lighting outside this range are not included in the act nor are some specialty bulbs (Energy Independence and Security Act of 2007).

LED lighting

Light Emitting Diodes commonly shorted to LEDs are semiconductors that emit photons in a process called electroluminescence. These photons are perceived by people as visual light and are very common in modern society. They were first introduced in the 1960s and used primarily in electronics. LEDs are small, energy efficient and durable making them ideal for this application. However, since their introduction many advances have been made making them suitable for a variety of other applications. LEDs are now available in a near infinite array of colors and the light output has greatly increased since the 1960s. LEDs can be found now in display boards, specialty lighting, flashlights and general building lighting. As the awareness of energy conservation increases the interest in LEDs for these other applications also increases. This is especially true for general building lighting. The Mark II dimmable LED light bulb manufactured by LED Waves produces the same lighting as a comparable 60 Watt incandescent bulb but with a power consumption of only 8.5 Watts. These LED light come with a 3 warranty and are rated to operate continuously for over four and a half years. The cost for these bulbs can be considerably more than traditional incandescent bulbs however. As of December 2010, the Mark II LED bulb sold on the LED Waves website for $45.95 each (Ehrlich 2010).

Energy Star ™ appliances

The Energy Star ™ program is system that rates the energy efficiency of consumer products like clothes washers, dishwashers, and refrigerators. The program was first created in the early 1990s under the direction of the Environmental Protection Agency. While specific products may vary, on average a reduction by 20 – 30% energy use is required to earn the

Energy Star ™ label. Energy Star ™ has grown significantly since its inception. The program has gone international being adopted by the EU, Taiwan, Australia, Canada, Japan, and other. The Energy Star ™ program has also moved past just rating products but also has a label for residential houses (Tugend 2008). Despite the growth of the program there are still some products lines which Energy Star ™ does not rate. Some of these products are dryers, microwave ovens, ovens, and ranges (Energy Star 2010).

Home Energy Management

Standby power loss

Standby power loss is the power that an electrical device uses even though it is not actively powered on. This is sometimes called its vampire draw. When consumers look at the energy performance properties of appliances or other electronic equipment the standby power draw is often times overlooked. This consumer oversight is understandable as for example intuitively the small power draw of a LED clock on a microwave seems insignificant. However, according to a March 9, 2006 article in "The Economist" a typical microwave uses 100 times the standby power when in use but is in standby more than 99% of the time. When calculated over the life of the microwave, the appliance will use more electricity to power the clock than to cook. This issue is compounded by the large number of devices that use standby power. These devices include televisions, computers, printers, DVRs, and even disconnected cell phone chargers. Dr Alan Meier (2006) of the Lawrence Berkeley National Laboratory (LBNL) said "We're moving from an electromechanical world that's on and off to an electronic world that's never off".

In 1998 the LBNL led by Dr. Meier was tasked to quantify the magnitude of the standby power loss problem. The results of the study were surprising. On average, standby power loss accounted for five percent of the total American home energy use but could be as high as 10%. At the time of the study five percent of the residential energy use equated to 64MWh or the sum power generation of 18 typical power stations. If the unnecessary power consumption of standby power could be avoided it would save American consumers more than three billion dollars a year (Meier 2006).

The issue has started to receive national attention and in January of 2006 the California Energy Commission enacted new regulatory legislation limiting the standby power draw on many common electronic devices to three watts per hour. Additionally, in 2001 Executive Order 13221 from President Bush stated that “when [government agencies] purchases commercially available, off-the-shelf products that use external standby power devices or that contain an internal standby power function, shall purchase products that use no more than one watt in their standby power consuming mode”. Governmental regulations along with technological improvements have created a bell-shaped curve of standby power draw over the past 40 years. Forty years ago electronic devices had very few peripheral functions requiring power when not in the on position so their standby power was typically zero. Fifteen years ago when electronics were very popular but before legislation and technological advancements were made, standby power draw was commonly 15 Watts or more per hour. In more recent years the average standby power draw is closer to one Watt per hour.

Given the alarming amount of energy that is wasted because of standby power loss, the next natural question is what can be done about it. For existing appliances the only practical option is to disconnect the device from the electrical receptacle. However, several devices are now sold to make this more convenient. One device is a power strip with an integrated on/off switch. These power strips have the advantage of being able to plug in multiple devices and thus be able to stop all of the standby power loss with one switch. This is particularly advantageous as the two areas of a home that have the highest losses are at the television/entertainment area

and at the home computer with related accessories. In both of these areas all of the equipment can be plugged into a single power strip and sever the connection with a single switch. The integrated on/off switch is also typically included in surge protectors commonly used to protect these high cost electrical devices. Still, going to an electrical receptacle to turn off equipment is not always convenient, especially if the receptacle is buried behind furniture. Another option that is available is a remote controlled switch. This devise has two parts. The first part is a devise that plugs into a receptacle. The plug-in receptacle has a port to have another devise plugged into it. Within the plug-in device is a low voltage relay that opens and closes the circuit to the appliance that is plugged into it. The second part of the remote-controlled switch is a transmitter that is often modeled to look like a common light switch. The transmitter is typically mounted to the wall and the user can turn off the power to an appliance by simply turning off the switch. There are several different manufacturers of the remote switch. A popular residential grade switch is called the Handy Switch and costs approximately ten dollars (Mays 2008).
Fortunately new appliances have options to make them much more efficient when in the standby mode, especially for low voltage equipment. The traditional way to step down the voltage required for smaller electronic devices is to use a charger with an iron core surrounded by copper wires. Newer chargers use what is called “switch mode” technology and use integrated circuitry to step down the voltage. Power Integrations in San Jose California provides these switch mode power supplies to companies such as Sony, Samsung, Motorola, Dell and Apple. Balu Balakrishnan, president of Power Integration, estimates that although these power supplies are a significant improvement, they only account for 20% of the four billion power supplies sold worldwide each year. The rest of the 80% are the traditional power supplies. The traditional power supplies are cheaper to make so manufacturers are not incentivized to provide them,

meaning that their customers will be paying the higher usage cost. New regulations as discussed earlier are mandating that the manufacturers use the switch mode or other high efficient power supplies and thus transfer the use cost back into the initial purchase price.

Programmable thermostats

According to the U.S. Department of Energy, heating and cooling represents nearly 50% of residential energy use. However, on average this load can be reduced by 10% by setting back the temperature 10 – 15 degrees for eight hours a day. This may seem intrusive at first glance but if you consider that in many cases a house is unoccupied for 10 hours a day the savings opportunity for this EEM seems viable. Many home owners try to reduce their heating and cooling demand by manually lowering and raising the temperature on their thermostats to coincide with when they are home. While this does lead to some savings the use of a programmable thermostat increases the savings for two main reasons. First, by adjusting the temperature setting of the thermostat manually the home owner runs the risk of forgetting or falling out of habit and thus losing the opportunity for savings. The second reason that a programmable thermostat is more effective is that it can adjust the temperature when the home owner is not available to adjust it manually. This is particularly advantageous at night when the home owners are sleeping. A programmable thermostat can keep the temperature at a comfortable level until after the home owner is asleep and then adjust it to a less energy intensive setting. Even for energy conscience home owners falling asleep and waking up to uncomfortable air temperatures is usually not worth the energy savings (US DOE 2010).

Energy Star ™ produced a manual titled “Guide to Energy-Efficient Heating and Cooling”. In this manual they provide recommend setting for programmable thermostats. See Table 2-1 for set points.

Programmable thermostats are not applicable in every condition. One example of where a programmable thermostat is not appropriate is with heat pumps. While in the cooling mode heat pumps act very similarly to traditional DX HVAC systems. When in the cooling mode relatively large swings in temperature to correspond to when the home is occupied will save energy. However, in the cooler months when heat is demanded large swing in temperatures cause a heat pump to operate inefficiently. Despite this limitation progress has been made and new special programmable thermostats are being introduce that can offer efficiencies even in the cooler seasons. Electric resistance heating elements like electric base boards are also not ideally suited for programmable thermostats. This is primarily because electric resistance heating is controlled directly from the line voltage; usually 120v or 240v. Relatively few manufacturers produce a line voltage programmable thermostat for this application and the cost is significantly higher than their low voltage counterparts. Additionally, programmable thermostats do not provide much savings with steam heating and radiant flooring. These types of heating have a long response time so there may be few or no on/off cycles throughout the day. It is important to note however that all of the examples mentioned where programmable thermostats are not effective are for heating and most commonly found in climates with long and severe winters. These heating methods are not commonly found in Florida (US DOE 2010).

Occupancy sensors

The U.S. Department of Energy estimates that approximately 10.1% of a residential building's total energy use is for lighting. Because of this relatively high draw home owners have looked to find ways of reducing the waste in their home lighting. One way that can help reduce lighting waste is with the use of occupancy sensors. Occupancy sensors are devices that detect the presents of people and open and close an electrical circuit accordingly. Lighting is a very common and practical application for occupancy sensors. Occupancy sensors can detect people in three different ways and often use them in combination. The first way is the detection of inferred light which is generated from body heat. These are fairly resistant to false-ons but require a line of sight to the occupant. A person tucked in a corner of a room may be left in the dark after the internal timer runs out. Another means of detecting people is by emitting a continuous ultrasonic pulse and then detecting any change in reflected sound. This type of occupancy sensor can detect people better than the passive inferred however is more susceptible to false-ons from air movement or movement in an adjacent room. The ultrasonic occupancy sensor also has greater limits in the range it can detect people. Passive inferred and ultrasonic detection are often used together to compensate for each other's limitations. Audio detection is a third means of detection. These occupancy sensors have a small microphone which closes the circuit if sound is detected above normal background noise. This type is the most sensitive but also the most susceptible to false-ons (Wilson 2003).

There are many designs available in which the device can be mounted on any surface in a room but the most common is for it to be combined with the entrance light switch. The switch mounted occupancy sensor usually includes an internal adjustable timer that will leave the circuit closed for a set period of time after it stops detecting an occupant. The switch also includes a manual override button where a user can turn on or off a fixture despite the occupancy of a room. This is especially important for bedrooms where having the lights on when occupied is not desired (Wilson 2003).

Energy dashboards

There are many studies that have been conducted that show that people's behavior is changed when they have real time feedback. As an example, people in general are aware that the slower they drive the more fuel efficient their car is. Despite this general knowledge, the monthly cost of fuel does not significantly influence the speed at which people drive. However, if a driver has access to real time data significant behavior changes have been observed. Dr. Kevin Little of the Informed Ecological Design, LCC calls this phenomenon the Prius effect. The phenomenon has been applied to the built environment via smart energy monitoring units sometimes called energy dashboards.

Energy dashboards are electronic devices that track real time energy consumption. For new construction there are a host of methods for tracking real time energy use however for retrofit residential projects the options are fewer. Most residential monitoring systems are wireless. These systems monitor overall consumption at the main electrical panel with 2 current transformer (CT) rings that clamp around the two leads into the panel. For individual plug in loads, wireless current transmitters plug directly into a receptacle and monitors usage. For hard wired loads like ceiling lights, CT rings with wireless transmitters can be clamped around the outside of the lead wires and transmit the data. All of the data collected is displayed on one or more central monitoring stations. These stations usually provide current electrical consumption in terms of kWh and cost as well as the potential to provide historical consumption information. Some electrical monitoring systems can transmit the information to a website so users can have access to the information away from the house (Wilson 2008).

Energy dashboards do not save energy directly but they can influence the behavior of the energy consumer. In 2006 and 2007 the Pacific Northwest National Laboratory (PNNL) in Washington State did a study in which they provided 112 home owners with real time energy consumption for their home. Over the course of the study the researchers found that on average the home owners reduced their consumption by 10%. A similar study was done in 2006 at the University of Oxford and the energy savings were found were consistent with the PNNL study.

Photovoltaic solar panels

When non-industry people are questioned about the green building movement often times the first thing that comes to mind is solar panels. While the existence of solar panels is widely known the specifics of how they work are not nearly as well understood. There are several different designs however the most common solar modules are made from silicon photovoltaic cells. The process for creating them is very precise which has led to prohibitively high cost in the past. Crystalline silicon is cut into round disks or wafers not more than a centimeter thick. The wafers are then carefully polished and treated to repair any imperfections created in the cutting process. After this process, chemicals called dopants are added to increase the charge of the polished wafer. Conductors are then applied on top of the wafers in a grid like pattern. This grid is visible on an assembled panel. Having the grid applied uniformly increases the efficiency of the unit. The conductors function is to capture the loose electrons from the wafers. If the grid is spread too far apart the conductors will not take advantage of all of the free electrons. If the grid is too dense it detracts the amount of solar energy that reaches the wafers and adds unnecessary cost to the unit. A sheet of non-tinted glass is then applied to the top of the panel. The glass is to allow solar energy through but at the same time protect the wafers and conductors from damage. On the underside of panel a thermally conductive panel is applied. Similar to the glass the underside panel protects the wafers and conductors from physical damage. However, unlike the top glass the underside panel needs to be very thermally conductive. Most solar energy not converted to electricity is transformed to heat. Excessive heat buildup can damage the unit as well as reduce efficiency. The underside panel must be a good medium to transfer this heat away from the wafers and conductors to the underside of the panel where the heat can be dissipated by the outside air (Solar Panel Information 2010).

These cells produce electricity directly from the suns energy without the use of a secondary medium. Sunlight contains energy in different forms and wavelength. One such form is the movement of photons. The photons strike the silicon molecules and essentially knock electrons loose. The movement of electrons is the definition of electricity so the capturing of these loose electrons by the integrated conductor grid is what generates the power. This process is called the photo-electric effect (Solar Panel Information 2010).

As a single panel does not create much electricity, multiple panels are tied together. It would seem intuitive that the more panels you have the more amperage created but it all depends on how they are wired together. Panels can be tied together in two different configurations; either in parallel or in series. Both produce electricity but have significant differences in their voltage and amperage which obviously is important depending on what is being powered. When a panel is said to be in parallel the positive terminals of the panel are tied to the adjacent panel's positive terminal. Similarly the negative terminals of the panel are tied to the adjacent panel's negative terminal. In this configuration voltage remains constant but the amperage is the sum of each panel. For example, assume you have 10 panels connected together in a parallel configuration and each panel is 12 volts and produces 5 amps. The cumulative output would be (10 panels x 5 amps) 50 amps at 12 volts. When a panel is said to be connected in series the connection and power produced is the exact opposite. A panel's positive terminal is connected to the adjacent panel's negative terminal. This is similar to the batteries in a flashlight. In this configuration the amperage is constant but the voltage is cumulative. For example, in the scenario above connecting in series would have a voltage of 120 (10 panels x 12 volts) at 5 amps. The distinction is important because of what the panels may be powering. 12 volt is very common for low voltage devises like exterior LED lighting, access control hardware or fire alarm devises. 120 volt is used for most interior plug in appliances and common electronics. Another important detail with photovoltaics is that the electricity produced is direct current or DC. This is the same as the power generated from a car battery. However because of the excessive electrical waste created when transferring DC power great distances the national power grid is on alternating current or AC. As such, an inverter in needed to change DC to AC if tying the panels into a buildings electrical system (Solar Home 2010).

An obvious disadvantage to photovoltaics is that they only create electricity during daylight hours. The traditional answer to this is to add batteries as an intermediate step between when power is generated and when it is needed. This is similar to the battery in automobiles except the source of the power is the engine through the alternator instead of solar panels however the technology is still well founded. However as an alternative to this, many municipalities have been offering to buy excess electrical power from private solar arrays when generation exceeds on site demand. Gainesville Regional Utilities participates in this program and offers to pay $.12/kWh for residential property (Roland 2008). In this scenario currency in the form of credits against future energy use take the place of batteries as the intermediate step between generation and use. This type of system has several advantages. The first advantage is obvious as it eliminates the need for expensive and environmentally questionable batteries. Another advantage has to deal with the timing of solar generation. For municipal power generation the peak times are during normal working hours. HVAC, lighting and all other modern necessities have the highest draw. At night, when activity is greatly reduced power demand drops. Because of the head and shoulders shaped demand curve, municipalities need to build the infrastructure to support peak demand to prevent uninterrupted service but have it idle for over half of the day when it isn’t needed. Solar generated power is ideal in this situation as it produces power concurrent to when it is needed the most. An opportunity exists for municipalities to reduce the cost of added electrical power infrastructure as populations increase if they require solar power production on new developments. If existing peak demand remains constant in the face of additional population then existing infrastructure will not need to be upgraded. These budgeted (or unbudgeted but future anyway) funds could be used to mitigate the upfront cost of solar power (Solar Panel Information 2010).

Effects of Specific Climates on EEMs

The core principle of sustainability is to have a close synergetic relationship between the built and natural environment. Working in harmony with the natural environment is also a good approach to energy conservation. However, throughout the Earth there are some vastly different types of climates. It is logical to think that to minimize a home's energy use its specific EEMs should be appropriate for its specific climate zone. Of the eight unique climate zones recognized by the Department of Energy, the entire state of Florida is categorized as hot/humid. As the name suggests the hot/humid climate zone has above average temperature and humidity when compared to the rest of the country. As such, the built environment will be expending a large percentage of its energy budget to move heat and remove water vapor from the indoor air. Solar energy is abundant in this climate zone which is can be a double-edged sword. Solar radiation can be a significant heat load adding to energy consumption; however, long day light hours create opportunities to replace artificial light with natural light. This creates the dual benefit of reduced energy use and improved light quality. Additionally hot/humid climates are ideal for photovoltaic power generation and solar water heating as the long days maximize the solar exposure and the frequent rains help keep panels clean. Hot/humid climate zones are more temperate year round which makes natural ventilation a possibility. Climate considerations are not perfect however, "…it serves a valuable purpose in promoting simple design approaches, rather than energy-intensive mechanical systems, for making buildings comfortable" (Givoni 1998).

Table 2-1. Energy Star ™ Recommendations for Residential HVAC Settings

Setting	Time	Set Point Temp: Heat	Set Point Temp: Cool
Wake	6:00 am	< 70 degrees	> 78 degrees
Day	8:00 am	Set back at least 8 degrees	Set up at least 7 degrees
Evening	6:00 pm	< 70 degrees	> 78 degrees
Sleep	10:00 pm	Set back at least 8 degrees	Set up at least 7 degrees

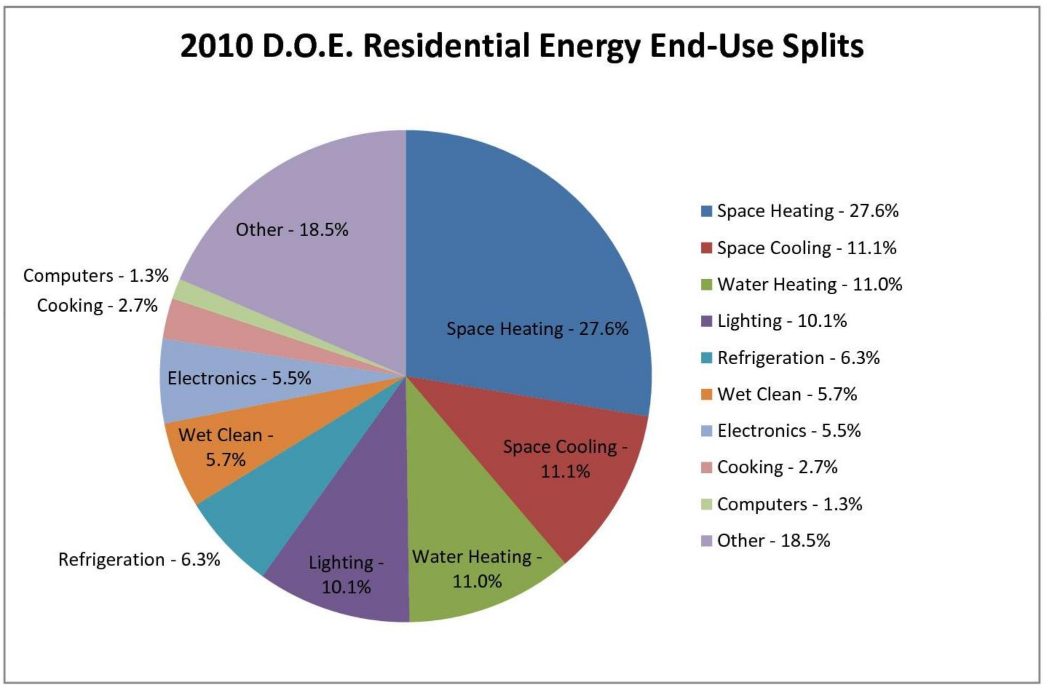


Figure 2-1. Department of Energy Residential Energy End-Use Splits.

Figure 2-2. Before and After Blower Cleaning. Image from CCS, LLC. of Gainesville, FL.

CHAPTER 3
RESEARCH METHODOLOGY

Overview

In this chapter the procedures for how the data were collected, analyzed and used to produces the research conclusions will be elaborated on. There are four areas in which data were collected. The first two dealt with common energy efficiency measures (EEMs) and typical characteristics of Florida housing. The others dealt with the effectiveness and cost of the EEMs on a typical Florida home. These are directly affected by the results of the first two. Once all of the data were collected and analyzed a matrix was provided to illustrate the results in terms of immediate capital cost, effectiveness in kilowatts conserved and return of investment duration.

Common Energy Efficiency Measures

The literature review chapter provided a topical review of the research that has been conducted on measures that will reduce energy consumption in a home. The first step in the research was to identify a list of commonly-used measures appropriate for Florida's climate. Many of the EEM identified had practical applications in the commercial sector. Because of the unique properties of a residence, many of those measures were not commonly used in the residential sector. EEM which were solely tailored for commercial construction were omitted from the study. Some identified EEM were highly theoretical and did not have a history of practical applications. These EEMs were also omitted from the study. The EEMs examined were primarily those that had well-established track records of yielding documented energy savings. EEMs endorsed by established organizations like Energy Star ™, the U.S. Department of Energy and the U.S. Green Building Counsel were included on the list. The only filter that would preclude an EEM endorsed by one of these established organizations was if the measure was exclusively designed for conditions not found in Florida. An example of this type of precluded measure would be geothermically heated water like that found in Iceland. Any preconceived notion or public perception that an EEM's cost benefit ratio would be prohibitively high was ignored. To determine the cost effectiveness of an EEM was the purpose of the study and unsupported opinions were not allowed to influence the findings.

Typical Florida Housing

To determine if the EEMs were effective, a quantification of typical single family housing in Florida needed to be established. The state of Florida is fortunate to have the Shimberg Center for Housing Studies which is a vast clearing house for residential housing data. With the resources of the Shimberg Center, the US. Census Bureau and the U.S. Energy Information Agency a list of common characteristics of Florida housing was created. With this information a typical Florida house can be modeled. This research calls this typical house the "Model House". The Model House is a model of a home made up of characteristics common to Florida houses. Each of the specified characteristics are characteristics that are shared by at least 50% of all Florida houses. All of the EEMs were tested for effectiveness and estimated for cost using the Model House. The use of the Model House provides a baseline in which to consistently measure the comparative effectiveness of the EEMs.

To assist in the visualization of the Model House and to more accurately quantify the cost estimates, a 3D model was created. The 3D model is a rudimental building plan and contains generic building information. In addition to the specified characteristics identified in the Model House design, all dimensions, wall heights, insulation R values with locations, and an exterior wall section were provided. The 3D model provides the necessary information to accurately estimate the cost of each of the EEMs. The 3D model also provides two additional peripheral benefits not related to this research. First, the 3D model provides a graphic representation of how the EEMs work. An example is that landscaping is not intuitively thought of as an EEM.

However, the 3D model can show that if a certain height tree is planted close to a window on the East or West elevation it can limit the solar heat gain without significantly impacting the exterior view. The other secondary contribution is that it provides information on how EEMs can impact the aesthetics of a home. Landscaping again can be a means of reducing energy consumption while also beatifying the home. However, a solar panel array can also reduce the demand on the central energy grid but can have a negative aesthetics reaction by the home owner. It is important to note that for this research aesthetics was not a factor when determining effectiveness.

Effectiveness of EEMs

The core of this research was focused on the effectiveness of the identified EEMs and their cost in relation to that effectiveness. The measure of each EEM was solely based on how much energy (measured in kilowatts) was reduced. The analysis was done by comparing the energy consumption before and after the EEM was implemented. In this study the baseline was the energy used in the Model House. To calculate energy consumption two methods were implemented. First, an energy modeling software package from Elite Software Development, Inc called "Energy Audit" was used. Energy Audit was largely used for EEMs that affected the entire house. These global measures include insulation improvement, HVAC upgrades, and lighting loads, among others. However, there are many measures which reduce the electrical draw on small devices and have smaller reductions for singular applications but in cumulative have a significant impact. An example would be the reduction in the standby power draw (sometimes called the vampire draw). These measures may not be able to be calculated on a software package designed for global energy reductions so manual calculations for these specific measures were completed.

Cost Estimates of EEMs

The second core component of this research was the estimate of the cost of each EEM. With the aid of the 3D model actual units, distances, and logistical data can be taken off and used in the estimates. The unit cost data was derived primarily from Reed Construction Data's RS Means. The medium to gather the RS Means unit costs was through their published catalogs and their online pricing software, CostWorks. The specific published catalogs used were RS Means for "Interior Home Improvement Cost", "Interior Cost", "Residential Cost Data" and "Contractor's Pricing Guide: Residential Repair and Remodeling". Estimates for general conditions, insurance rates, and supervision were also added to the estimates.

Matrix of Results

Once the EEMs were identified, reviewed for effectiveness, and priced a matrix was created to illustrate the results. The matrix ranks the EEMs in order of their cost effectiveness ratio (CER). The cost effectiveness ratio was defined as the total initial capital expense divided by annual cost savings in energy (CER = capital expense/annual savings). The energy cost was based on the average energy cost per kilowatt hour in the state of Florida. Additionally, based on current finance rates the length of time to return to the owner the initial capital expense was provided.

CHAPTER 4
RESULTS AND ANALYSIS

Overview

The results and analysis is divided into two main sections. The first section elaborates on what "typical" Florida housing is and explores what are common EEMs available to home owners. The second section uses the information compiled in the first section to determine effectiveness and cost.

Results and Analysis: Section One

Typical Florida Single Family Housing

To determine the common characteristics of Florida housing, information from The Shimberg Center for Affordable Housing (2010), U.S. Census Bureau (2006 – 2008), and the U.S. Energy Information Administration (2005) was collected and analyzed. The characteristics found in typical single family housing were separated into four categories; General Information, Construction Characteristics, Appliances, and Furnishings. When creating the list of common characteristics reasonable extrapolations of the data were needed. For example the average Florida house hold size is 2.5 people. To create a realistic scenario having a half of a person is impossible so the model house rounded up to 3 people. Similarly the average Florida house has 2.38 bedrooms. Having a fraction of a bedroom would not create a realistic model so as the total house hold size was rounded up so also was the number of bedrooms. This is a limitation to the research that will be expanded upon in the conclusion chapter. A summary of "General Information" from a typical Florida house can be found in Table 4-1.

Another important component in defining a typical Florida house is the construction characteristics. The characteristic relate directly to the structure and construction methods used when building the residence. A summary of the construction characteristics can be found in Table 4-2.

Another key component of the typical Florida house is its appliances. The appliances represent non-HVAC residential equipment used to satisfy basic human needs like hygiene, cooking, and cleaning. Entertainment or business equipment is included in another category to follow. The appliance category is extremely important as much of the monthly energy budget is used with these devices. Table 4-3 provides the typical appliances for a Florida single family house.

Home equipment that is related to personal entertainment or business has been categorized in this research as furnishings. Similar to the appliance category, furnishing can be a significant portion of the home owners monthly utility cost. In Table 4-4 a summary of common furnishings found in Florida single family homes is provided.

3D Model

Once the data was collected to identify what the characteristics of typical Florida house are a 3D building information model (BIM) was needed (Figure 4-1). On the surface creating a 3D model may not seem necessary however it aided the study in three key ways. First, the 3D model was transformed into a 2D floor plan (Figure 4-2). The 2D information was then used to do quantity take-offs for the EEMs cost estimates. The second function that the 3D model was used for was to create a simulated structure in which to test the EEMs. An example of this was when testing the savings associated with LED lighting. Individual rooms with specific sizes and light intensities were needed to simulate the lighting power use. Without the model there would not be enough specific data to accurately simulate the baseline energy use or the effect of the applied EEM. The third benefit of using the 3D model is that it helps establish the parameters of the experiments. Many characteristics of the model house like the building shape or lighting locations are most accurately and easily illustrated graphically. The 3D model documents the parameters of the experiment and allows for the results of the study to be reproduced and built upon for future research.

There are many different 3D building information modeling (BIM) software packages available. For this study Home Designer by Chief Architect Software was used. This software package was selected because it is designed for residential applications, is easy to use, has a large library of preloaded building components and is inexpensive to purchase. Home Designer is not nearly as powerful as Revit Architecture by Autodesk however Chief Architect Software does make commercial grade versions of Home Designer that may be closer. As of the November 2010 the package could be purchased for 99 dollars which was comparable to other competing products with similar levels of sophistication. In addition to the three core benefits of using a 3D model mentioned above, using Home Designer and its preload library of building components gave the model a more “real life” feel. Cosmetic additions like landscaping, furniture, paint colors and finishes created a more realistic representation of an actual real world house (See Figures 4-3 through 4-7).

Common Energy Saving Measures

The second set of information that needed to be collected in the first section was the list of common energy saving measures. These measures were identified in several establish green organizations like the U.S. Department of Energy, Energy Star ™ and the U.S. Green Building Council. The following list provides a summary of the common EEMs tested on the model house.

Space conditioning.

- Ceiling Fans: Raises the temperature that house residences are comfortable at.

- HVAC Tune-Up (re-commissioning): Re-commissions HVAC equipment so that it operates more efficiently.

- Leaking HVAC Ductwork: Reduce the air loss through ductwork so that more cool air is delivered to conditioned space and not lost in unconditioned space.

- High SEER AC Unit: Replace existing unit with a high efficiency HVAC unit.

Water heating.

- Low Flow Shower Heads and Aerators: Reduction in water reduces energy needed to heat it.

- Solar Water Heating: Using solar energy to heat water instead of using electrical energy.

Building envelope.

- Window Film: Reduces solar heat gain through windows and glass openings.

- Blow-In Attic Insulation: Increasing insulation in attic and lower heat gain into conditioned space.

- Retro – Foam for Wall Insulation: Seals penetrations in walls to reduce air infiltration.

- Low E Glass: Replace existing windows with higher efficiency windows.

- Window Awning: Reduces solar heat gain through windows by blocking direct solar energy.

- Light Tubes / Skylight: Reduce the need for artificial light by taking efficient advantage of natural lighting.

- Strategically Placed Landscaping: Reduces solar heat gain through windows when placed so that the shade provided reduces solar heat gain through glass openings.

Lighting, appliances, miscellaneous electrical loads.

- Compact Fluorescent Lights: Use of high efficiency lighting to reduce energy consumption.

- LED Lighting: Using high efficiency light emitting diode (LED) type lighting to reduce energy consumption.

- Energy Star ™ Appliances: Replace existing appliances with high efficiency, energy star rated appliances. Specific appliances to be replaced are the clothes washer, refrigerator and dish washer.

Home energy management.

- Standby Power Loss: Power used when devices are plugged in but not being actively used.
- Programmable T-Stats: Manages HVAC unit so it reduces run time when not needed.
- Occupancy Sensor: Automatically turns off lights when residences are not in the room.
- Energy Meter: Allows home residence to be informed of real time energy use so that they can make behavior changes.
- Photovoltaic Solar Panels: Adding energy producing solar panels to reduce the demand on the central energy grid.

Results and Analysis: Section Two

Effectiveness Overview

The second section of this chapter uses the compiled data collected in the first section to measure the effectiveness and cost of each EEM. The effectiveness of each EEM was measured in total reduction in electrical consumptions using the Model House as a baseline. A detailed summary of the Model Houses energy consumption can be found in Appendix A. Each measure's effectiveness was computed as a standalone item. The calculation of effectiveness was either done by computer simulation or by manual calculations. As a general rule, EEMs that had more global impacts like with attic insulation were computed using the computer simulation. To calculate the effectiveness for smaller or device specific EEMs manual calculations were used.

Energy Modeling Software – eQUEST

Similar to the BIM software available, there are many different energy modeling programs to choose from. For this study eQUEST version 3.64 was used. eQUEST is an acronym for QUick Energy Simulation Tool. The software was selected for several key reasons. First, it is endorsed by the U.S. Department of Energy and a favorable review of its performance can be found on the DOE website (US DOE 2011). Additionally, eQUEST is the energy modeling software taught at the M.E. Rinker Sr. School of Building Construction at the

University of Florida. The development of the software was paid for by the state of California and made available to the public at no cost. The package provides whole building modeling for both residential and commercial projects. It comes with a large library of preloaded building components, schedules, equipment performance data, and default settings creating an environment where accurate energy models can be created by novice energy modelers. The program also allows the user to create custom building assemblies and unique occupancy schedules making the software ideal for this study (Figure 4-8).

eQUEST – data collection

To create a model in eQUEST there are steps or levels of input required. The first step is the collection and organization of the building characteristics data. Much of the building data came from the U.S. Census Bureau, Shimberg Center and the EIA as described earlier in the chapter. While there was overlap between the agencies the U.S. Census provided the basic characteristics of the occupants, the Shimberg Center described the building construction type and components, and the EIA outlined energy use patterns. In addition to these organizations the 1987 Florida Energy Code was used to supplement missing details of some construction component. The 1987 code was used as the median Florida house was built in 1988 and was assumed to be permitted the year before. Where modeling inputs like building perimeter length were not available assumptions were made and documented in the building protocol (see Appendix R).

eQUEST – building geometry

Once the building and occupant data is collected the energy model can start to be created. The software package Home Designer was used to create a floor plan. From the floor plan a p-line drawing was then created in AutoCAD by Autodesk. The p-line drawing traced the exterior perimeter as well as the outline of the interior rooms. The AutoCAD file was then imported into eQUEST and used to create the building's shape (Figure 4-9).

eQUEST - building components

As mentioned earlier, eQUEST comes with an extensive library of preload building components as well as the ability to create custom components or assemblies. This study required the use of both functions. For example, in 1987 the minimum insulation value required for exterior walls was an R-4. This can be accomplished with 5/8" stucco, 8" CMU block, a 5/8" air space and 5/8" gypsum board. Current Florida code does not allow for such a low R value wall assembly and as such is not included in the eQUEST library. However, to accurately model the energy performance the wall components were selected from the library and a custom assembly was created. In some cases where specific construction data was not available building components out of eQUEST's library were used. For example the specific type and thermal properties of the typical Florida house front door was not available. For this case an insulated metal door was assumed and the average thermal properties of this type of door were pulled from the library and included in the model (Figure 4-10).

eQUEST – zones and schedules

A critical part of energy modeling is the creating of zones and schedules. For this study a zone is synonymous with an individual room. Zones provide the boundaries for the different lighting intensities and equipment energy use levels. The zone's boundaries are created by importing an AutoCAD file in eQUEST similar to the creation of the building shell. The specific characteristics of the zone can then be input into the program. In addition to building zones schedules are a critical part of energy modeling. The energy draw for lighting is different at 9:00am than at 9:00pm. Similarly the energy need for home equipment is different on a workday than from a weekend. A schedule simulates these fluctuating energy use patterns and allows eQUEST to model the effects (Figure 4-11).

eQUEST – energy simulation

Once all of the information has been entered into the program and a model is created an energy simulation audit can be run. eQUEST will generate a report that shows the energy used per month broken down into the major energy use categories. The energy use in the baseline Model House can be seen in Appendix A. To test the effectiveness of the different EEMs a copy of the baseline energy model was created. The copy of the energy model is then modified to reflect the implementation of the EEM. An energy simulation audit was then run on the new energy model and compared with the baseline. The difference in energy use between the new energy model and the baseline is the net energy savings of the EEM.

Energy Efficiency Measures

The following paragraphs provide a description of the EEMs tested. The majority of the EEMs tested used the energy modeling software to determine the reduced energy consumption. The results of each of the EEMs energy simulation audits can be found in Appendix B – Q. However, for some EEMs it was more appropriate to do a manual calculation of the energy reduction. The manual calculations are show below with the respective EEM.

Space Conditioning

Ceiling fans

This EEM employed ceiling fans to reduced energy consumption by raising the air temperature that the home occupants are comfortable at by three degrees. In the baseline model there is only one ceiling fan in the house located in the central living room. This EEM adds a ceiling fan in each of the three bedrooms. This could potentially be a means of reducing the heat load during the winter months by reversing the fan direction and drawing down warm air from the ceiling space. However, using the fan in the winter months could also create a wind chill effect. For this reason this EEM was assumed only to be applied during the warmer months. The calculation of energy savings was a combination of the energy modeling software and a manual calculation. The software was used to calculate the reduced cooling load. The software does not model specific pieces of equipment well so the direct energy draw from the three fans was calculated manually. The annual savings in energy cost is $50.63 with an initial capital input of $888.87. The energy savings and capital expense summary can be seen on Tables 4-5 and 4-6. The energy model simulation using this EEM can be seen in Appendix B.

The calculation for the added load for the 3 fans is as follows.

Reduced HVAC load from Computer Simulation Model = 1,420kWh/year

Additional Electrical Load from Ceiling Fan

75 Watts/hr * 12hr/day *365days/year * 3 fans = 985,500 Watts or 985.5kWh

Total Energy Conserved = Heat Load Reduction – Added Direct Fan Consumption

1,420kWh – 985.5kWh = 434.5kWh

Energy Cost Savings

434.5kWh * $.1165/kWh = $50.62

HVAC tune-up (re-commissioning)

The HVAC Tune-up EEM provides the HVAC unit a "tune-up" to optimize performance. The operation is usually performed by a professional contractor who will provide services like recharging the refrigerant, cleaning the coils, lubricating mechanical components, adjusting belts and removing air obstructions from the condensing unit. By servicing the unit the efficiency can be increased by ten percent but for this research a more conservative five percent will be assumed. The annual savings in energy cost is $44.27 with an initial capital input of $528.58. The energy savings and capital expense summary can be seen on Tables 4-7 and 4-8. The energy model simulation using this EEM can be seen in Appendix C.

Sealing leaking HVAC ductwork

The Department of Energy reports that in many older homes there is an average of 20% conditioned air loss in a home's ductwork. In this measure it is assumed that the Model House has a similar 20% loss. This measure will include repairing torn ductwork, resealing duct connections, un-kinking flexible ductwork and resealing the air handler resulting in a reduction of air loss to 10%. Often times the cause of the leaks is due to duct tape that has failed over time. The assumed repair includes in part replacing failed duct tape with a mastic duct adhesive that meets current Florida code. A 50% reduction in air loss is a conservative value used to account for sections of ductwork and the air handler that are inaccessible for repair. The annual savings in energy cost is $87.38 with an initial capital input of $1,591.71. The energy savings and capital expense summary can be seen on Tables 4-9 and 4-10. The energy model simulation using this EEM can be seen in Appendix D.

High SEER AC units

The median Florida single family house was built in 1988. At that time, the Florida Energy Code required a minimum HVAC SEER of 9. However, because of the age of the house it is likely that the HVAC unit would have had to have been replaced. For this simulation it is assumed that the Model House's HVAC unit was replaced in 2003 with a SEER 12 but has regressed to a SEER 10. This measure will replace the Model House's existing HVAC with an Energy Star ™ Rated SEER 14 unit. The annual savings in energy cost is $250.48 with an initial capital input of $3,231.41. The energy savings and capital expense summary can be seen on Tables 4-11 and4-12. The energy model simulation using this EEM can be seen in Appendix E.

Hot Water

Low flow shower heads and aerators

The energy required to heat water represents a significant percentage of a home's total energy consumption. In 2010 the DOE reports that water heating represents 11% of all residential energy use and is only behind space heating and cooling in total energy draw (Figure 2-1). For this EEM two low flow shower heads and faucet aerators will be applied to both bathrooms in the Model House to reduce hot water demand. The total hot water used was reduced from 28,250 gallons/year to 22,995 gallons/year or approximately 19%. This calculation only takes into account the hot water reduced. However, this measure will also have a peripheral benefit of reducing unheated water use as well which is not considered in this energy consumption study. The annual savings in energy cost is $50.10 with an initial capital input of $49.52. The energy savings and capital expense summary can be seen on Tables 4-13 and 4-14. The energy model simulation using this EEM can be seen in Appendix F.

Solar water heating

For this measure a solar water heating system will be used instead of an electric storage tank style water heater. The solar unit will have a collection plate on the roof and will circulate heated water to a central 120 gallon storage tank. The storage tank will have two electric backup heating elements used for 20% of domestic water heating. The backup heating will be used when the storage tank is depleted of hot water without sufficient time to heat additional water with solar energy. This is likely to happen with large immediate hot water draws or with extensive periods not conducive to solar thermal harvesting. The annual savings in energy cost is $210.87 with an initial capital input of $5,604.99. The energy savings and capital expense summary can be seen on Tables 4-15 and 4-16.

Building Envelope

Window film

This EEM provides a low-E window film on all exterior windows. The product used was 3M's Prestige line series 70 window film. Low E film is used to reduce the amount of solar heat gain. Although advances have been made with spectrally selective film, the reduced solar heat gain usually also reduces the amount of visible light albeit not necessarily to the same proportion. The specific product used for this study with the window glazing has a combined visible light transferred of 69%, an infrared rejection of 97%, ultraviolet reflection of 99.9% and a shading coefficient of .58. The annual savings in energy cost is $55.59 with an initial capital input of $568.87. The energy savings and capital expense summary can be seen on Tables 4-17 and 4-18. The energy model simulation using this EEM can be seen in Appendix G.

Increased attic insulation

In this EEM additional insulation will be added to the attic floor. The 1987 Florida Energy Code required a minimum of R19 insulation be used for residential homes. For this simulation an additional 6" of blown-in insulation was added. This additional insulation will increase the total R value to 42. This is slightly higher than the DOE's recommendation of R38 for this climate type however 6" is a common unit of measure that this type of insulation is purchased in. The annual savings in energy cost is $10.49 with an initial capital input of $1,101.83. The energy savings and capital expense summary can be seen on Tables 4-19 and 4-20. The energy model simulation using this EEM can be seen in Appendix H.

Retro-foam in walls

In this measure air penetrations in the wall are located and sealed with expansive foam insulation. The process involves using thermal cameras and other heat detection equipment to locate areas of high outside air infiltration. At these points holes are drilled into the CMU cavities and filled with expansive foam. Often times these locations are at electrical junction boxes where the block has been penetrated on one side to provide space to install the box. Window perimeters are another area of high air infiltration that can be sealed with foam or caulk. Despite the added foam insulation the R value added to the walls is marginal. In this simulation the expected effectiveness of the retro-foam is that it will reduce the air infiltration of the home by 30% overall. The annual savings in energy cost is $20.97 with an initial capital input of $7,217.69. The energy savings and capital expense summary can be seen on Tables 4-21 and 4-22. The energy model simulation using this EEM can be seen in Appendix I.

Low-E glass

In this measure the Model House's 1/8" single hung operable windows are replaced with double panel Low-E glass. In addition both sliding glass doors are replaced with new doors with similar Low-E glazing. The Low-E glass panes are ¼" in thickness with a ½" air gap between the glass layers. The annual savings in energy cost is $51.26 with an initial capital input of $5,647.52. The energy savings and capital expense summary can be seen on Tables 4-23 and 4-24. The energy model simulation using this EEM can be seen in Appendix J.

Awnings

For this measure a fabric window awnings will be applied to all of the windows and sliding glass doors on the East, West and South Elevations. The awnings will be used to reduce the amount of thermal energy penetrating the building envelope and lower the cooling load. The awnings have an aluminum frame anchored to the CMU wall. The frame supports a fabric covering which provides the shading. The awning covers the length of the window opening and extends horizontally 3 feet from the face of the wall. The annual savings in energy cost is $64.08 with an initial capital input of $1,691.49. The energy savings and capital expense summary can be seen on Tables 4-25 and 4-26. The energy model simulation using this EEM can be seen in Appendix K.

Skylight

In this EEM two skylights were added to the Model House. The two 4’x 4’ skylights are located in the dining room and the living room. A five foot light well was required to gain access from the roof level through the attic. The light well was framed with wood 2”x4”studs with a level 4 painted drywall finish. Unlike all of the other EEMs tested this measure had a negative energy savings. This EEM would add to the annual energy consumption of the house. The minimal amount of lighting savings was negated by the additional load placed on the air conditioning system. The annual savings in energy cost is $<11.65> with an initial capital input of $2,998.19. The energy savings and capital expense summary can be seen on Tables 4-27 and 4-28. The energy model simulation using this EEM can be seen in Appendix L.

Strategically placed landscaping

In this measure two large trees are strategically placed to provide shading at glazed openings. This study assumed the trees were red maples as this species has a full canopy and large broad leaves to maximize the shading. However, the results of the experiment would be similar for any tree that had similar shading characteristics. The trees are specifically located outside the windows of the East and West bedrooms. The energy simulation was run at the point when the trees are just planted however the savings will increase as the trees grow in size. The annual savings in energy cost is $11.65 with an initial capital input of $1,074.87. The energy savings and capital expense summary can be seen on Tables 4-29 and 4-30. The energy model simulation using this EEM can be seen in Appendix M.

Lighting, Appliances, Miscellaneous Electrical Loads

Compact fluorescent lights

For this experiment an average light level of 12 foot-candles was assumed. Additionally, the baseline model assumed that the primary source of light in the house came from 60W incandescent lamps which emit approximately 800lumens. With these assumptions the total number of incandescent light bulbs can be calculated by multiplying the house area (1,803sqft) by the light intensity (12 foot-candles) and then divided by the per bulb lighting intensity (800 lumens). This calculation reveals that 27 bulbs are needed to provide the Model House an average lighting intensity of 12 foot-candles. If you multiply the total number of bulbs (27) by their wattage (60) and then divide the result by the area of the house (1,803) you would derive the average power intensity of .9 Watts/sqft. eQUEST uses watts/sqft as the unit of measure for calculating lighting intensity. For this EEM the 60 W incandescent light bulbs were replaced with high efficiency compact fluorescent light bulbs. The CFL assumed used 14 W to provide an equivalent light output of 800lumens each. The average light level before and after the EEM was implemented remained 12 foot-candles. The annual savings in energy cost is $475.32 with an initial capital input of $59.42. The energy savings and capital expense summary can be seen on Tables 4-31 and 4-32. The energy model simulation using this EEM can be seen in Appendix N. A limitation to this study is that it does not take into account the risk of damaged lamps. If CFL lamps are damaged before their expected lifespan it will influence the proforma of the EEM.

LED lighting

This measure is very similar to the CFL measure however instead of CFL lighting the incandescent lamps are replaced with LED lamps. However, a key difference with LED lighting is that LED lamps do not emit the same lighting intensity as incandescent or CFLs. As opposed to the 800 lumens emitted from incandescent lamps the LED light bulb assumed only emits 510 lumens. This means that it will take 43 bulbs to provide the same lighting level as 27 incandescent bulbs. The annual savings in energy cost is $481.15 with an initial capital input of $2,104.28. The energy savings and capital expense summary can be seen on Tables 4-33 and 4-34. The energy model simulation using this EEM can be seen in Appendix O. Similar to the CFL this study does not assume any of the LED lamps will be damaged before their expected lifespan. However, many of the LED lamps come with 5 year warranties which helps mitigate the risk.

Energy Star ™ appliances – clothes washer

This measure is one of three that test the energy savings by using an Energy Star ™ appliance. This specific EEM is for replacing a clothes washer with a new Energy Star ™ model. By using the published data provided by the Energy Star ™ website the savings were manually calculated as shown below. About two thirds of the energy saved came from the reduced hot water use. The other third came from the reduced direct energy needed to run the appliance. The cost estimating of all of the Energy Star ™ appliances came from actual vendor pricing. As RS Means does not track the pricing of Energy Star ™ appliances specifically the pricing was gathered from Home Depot's ™ website. The annual savings in energy cost is $29.76 with an initial capital input of $627.39. The energy savings and capital expense summary can be seen on Tables 4-35 and 4-36.

Direct Electricity Use

Traditional Unit Electricity = Total Loads/Week *52 Weeks * 1.242kWh/load
4 loads/week * 52 weeks *1.242kWh/load = 258.34kWh/year

Energy Star ™ Unit Electricity = total loads/Week * 52 Weeks * 1.272kWh/load * 70%
4 loads/week *52 weeks *(1.242kWh/load *(100% -30%)) = 180.84kWhs/year

Reduction from Traditional to Energy Star ™ Electricity = Traditional – Energy Star ™
258.34kWh – 180.84kWh = 77.50kWhs/year

Energy to Heat Water
Traditional Hot Water Use = loads/week * 52 weeks/year *gallons/load
2 loads/week * 52weeks/year * 31.07gallons/load = 3,231.28 gallons/year

Energy Star ™ Hot Water Use = loads/week * 52 weeks/year *gallons/load * 50%
2 loads/weeks * 52 weeks/year * (31.07 gallons/load * 50%) = 1,616 gallons/year

Reduction from Traditional to Energy Star Hot Water Use = Traditional – Energy Star ™
3,231.28gallons/year – 1,616 gallons/year = 1,616 gallons/year

Energy Required to Heat Water
Heat added to water = Hot Water Temperature – Municipal Water Temperature
120 degrees – 75 degrees = 45degrees

Electrical Energy Required to Heat Water
(1,616 gallons/year * (8.35lbs/gallon) = 13,494lbs/year
13,494lbs * 45 degrees = 607,212btu
607,212btu * (1Wh/3.41214btu) * (.80 inefficiency) = 142,365Wh or 142.37kWh

Total Energy Conserved = Direct Electrical Energy + Electricity for Water
77.50kWh + 142.37kWh = 219.9kWh

Energy Cost Savings
255.46kWh * $.1165/kWh = $29.76

Energy Star ™ appliance – refrigerator

The energy reduced by using an Energy Star ™ refrigerator was the second of three appliances tested. For a refrigerator to receive an Energy Star ™ label it must use 20% less energy than a comparable unit. They define a comparable unit as a similar model with an energy draw of 529kWh/year. With this information the manual calculation can be performed as shown below. The annual savings in energy cost is $12.33 with an initial capital input of $712.59. The energy savings and capital expense summary can be seen on Tables 4-37 and 4-38

Total Energy Conserved.
Energy Saved With Energy Star ™ Refrigerator = Traditional Energy Use * 20%
529kWh/year * 20% = 105.8kWh/year

Energy Cost Savings
105.8kWh/year *.1165/kWh = $12.33/year

Energy Star ™ appliances – dish washer

The reduced energy from using an Energy Star ™ dish washer was the third of three appliances tested. See the manual calculation for the savings below. In contrast to the clothes washer approximately one third of the energy saved comes from water heating and two thirds comes from the direct energy needed to run the appliance. The annual savings in energy cost is $14.02 with an initial capital input of $549.65. The energy savings and capital expense summary can be seen on Tables 4-39 and 4-40.

Direct Electricity Use

Traditional Unit Electricity = Total Cycles/Week *52 Weeks * kWh/cycle

4.13 cycles/week * 52 weeks/year *1.67kWh/cycle = 358.65kWh/year

Energy Star ™ Unit Electricity = Total Cycles/Week * 52 Weeks/Year * kWh/cycle

4.13 cycles/week *52 weeks/year *1.33kWh = 285.63kWh/year

Reduction from Traditional to Energy Star ™ Electricity = Traditional – Energy Star ™

358.65kWh – 285.63kWh = 73.02kWh/year

Energy to Heat Water

Traditional Hot Water Use = cycles/week * 52 weeks/year *gallons/cycle

4.13 cycles/week * 52weeks/year * 6 gallons/cycle = 1,288.56 gallons/year

Energy Star ™ Hot Water Use = cycles/week * 52 weeks/year *gallons/cycle

4.13cycles/weeks * 52 weeks/year * 4 gallons/cycle = 859.04 gallons/year

Reduction from Traditional to Energy Star ™ Hot Water Use = Traditional – Energy Star

1,288.56gallons/year – 859.04 gallons/year = 429.52 gallons/year

Energy Required to Heat Water

Heat added to water = Hot Water Temperature – Municipal Water Temperature

120 degrees – 75 degrees = 45degrees

Electrical Energy Required to Heat Water

(429.52 gallons/year * (8.35lbs/gallon) = 3,586.49lbs/year

3,586.49lbs * 45 degrees = 161,392btu

161,392btu * (1Wh/3.41214btu)*(.8 for inefficiency) = 37,839Wh or 37.8kWh/year

Total Energy Conserved = Direct Electrical Energy + Electricity for Water

73.02kWh/year + 37.8kWh/year = 110.86kWh/year

Energy Cost Savings

120.32kWh/year * $.1165/kWh = $14.02/year

Home Energy Management

Standby power loss

In the standby power loss EEM a device was used to disconnect appliances from their power source when not being actively used. There are a variety of devices on the market but for this calculation two “handy switches” were used. The intention is that by applying these switches it becomes convenient enough for the resident to disconnect the power when the home equipment is not actively needed. The concept is that without the switch it would be too inconvenient to disconnect the power and the resident would elect to leave them plugged in and forego the savings. The devices were placed at the two locations with the highest wasted standby power; the computer station and central entertainment center. See the manual calculation for the savings below. The annual savings in energy cost is $17.01 with an initial capital input of $38.13. The energy savings and capital expense summary can be seen on Tables 4-41 and 4-42.

Total Energy Conserved:

Number of Units * Average Standby Draw * Duration

5 units * 10 Watts * 8 hours = 400Wh/day or .4kWh/day

.4kW/day * 365 day/year = 146kWh/year

Energy Cost Savings

146kW * $.1165/kWh = $17.01

Programmable thermostat

This EEM provides savings on the homes cooling and heating system by using a programmable thermostat. The programmable thermostat allows the resident to adjust the set point higher (or lower setting depending on the season) when there is not a demand for space conditioning. Essentially it is a low tech way of making a building produce cooling or heating only when it is needed. The programmable thermostat generally has three set back points. In the case of cooling, the lowest temperature set point is at the period when the building is most likely to be occupied. The second lowest set point is after the resident goes to sleep and elects to raise the set point to save energy. The highest temperature set point would be when there is no one in the building and no need for space conditioning. The annual savings in energy cost is $160.77 with an initial capital input of $265.41. The energy savings and capital expense summary can be seen on Tables 4-43 and 4-44. The energy model simulation using this EEM can be seen in Appendix P.

Occupancy sensor

The occupancy sensor EEM reduces the time that lights are turned on when not actively needed. The savings comes from reducing direct electrical consumption from the light use and from less demand on the HVAC system. In this simulation integrated light switch type occupancy sensors will be installed in all 3 bedrooms, the kitchen, dining room and living room. ASHRAE 90.1, table G3.2 approximates that the lighting load will be reduced by 10% when using automatic lighting controls. This approximation will be used for this research as well. The annual savings in energy cost is $51.26 with an initial capital input of $475.13. The energy savings and capital expense summary can be seen on Tables 4-45 and 4-46. The energy model simulation using this EEM can be seen in Appendix Q.

Energy dashboards

The use of energy dashboards does not save energy directly but modifies occupant behavior by providing real time energy use feedback. For this experiment, an energy dashboard system called the Envi by Power Save Inc was simulated. The system includes a wireless transmitter located in the electrical panel. In addition, four 220volt current transformers are used to monitor the energy draw from the air handler, condenser unit, water heater, and oven. Also included with the experiment are two, 120volt wireless appliance transmitter to monitor the home entertainment center and computer area. The power use information is sent wirelessly to a portable display that shows current energy use and historical information. The University of

Oxford did a study and found that a similar energy dashboard system reduce the average energy consumption by 10%. For this study the same 10% reduction was used. The annual savings in energy cost is $264.46 with an initial capital input of $1,223.17. The energy savings and capital expense summary can be seen on Tables 4-47 and 4-48.

Photovoltaic panels

In this measure an 8' x 15' photovoltaic array will be added to the Model House. The energy produced is less than the house is consuming so a utility buy back option was not considered. The average number of direct sunlight hours in Florida is 4.5 hours per day. Although there are more daylight hours in a day this number accounts for overcast days, cloud cover, and less intense sunlight near dawn and dusk. The system assumed for this experiment can produce 10 Watts of energy for every square foot of the array at full sun. The system will be mounted over the garage where the roof angles toward the south. The annual savings in energy cost is $229.62 with an initial capital input of $9,793.83. The energy savings and capital expense summary can be seen on Tables 4-49 and 4-50. The manual calculation of energy produced can be seen below.

Size of unit = length * height
15' * 8' = 120sqft

Total Energy Conserved
Array output per hour = size x watts/hour
120sqft * 10 Watts/hour = 1200 Watts/hour

Yearly energy output = average direct sun rays * watts/hour * 365days/year
4.5hrs/day * 1,200 Watts/hour * 365days/year = 1,971,000w/year or 1,971kw/year

Energy Cost Savings
Cost Savings = kW/year *.1165/kWh
1,917 * $.1165/kWh = $229.62

Table 4-1. Typical single family housing: general information

Structural Characteristic	Structural Quantity/Affirmation	Resident Characteristic	Resident Quantity/Affirmation
Area	Florida	Number of occupants	3 people
Residence type	Single family	Tenure in house	6 years
Median year built	1988	Median just value	$149,000
Median size	1,800sqft	Mortgage on house	Yes
Total rooms	7	Mortgage/Total income	31%
Bedrooms	3	Average utility cost	$131/month
Bathrooms	2	Someone home during day	No
Garage	2 car	Automobiles owned	2

Table 4-2. Typical single family housing: construction characteristics

Characteristic	Quantity/Affirmation
Exterior structure	Reinforced C.M.U. wall
Foundation	Monolithic concrete slab
Exterior wall finish	Cement stucco with painted finish
Interior walls	Wood framing with painted gypsum board
Window type	Single pane glass in frame
Roofing type	Asphalt shingle
Truss type	Wood truss
Window/Floor ratio	15%
Access to natural gas	Yes
Use of natural gas in house	No
Central heat and air system	Yes
Heat pump	No
Area of house conditioned	100% (excluding garage)
Programmable thermostat	No
Large trees shading house	No

Table 4-3. Typical single family housing: appliances

Characteristic	Quantity/Affirmation
Oven	1
Self cleaning	Yes
Integrated range	Yes
Fuel source	Electric
Refrigerator	1
Frost free	Yes
Top bottom door Style	Yes
Exterior water/ice Dispenser	No
Energy Star ™	No
Size	15 – 18cuft
Age	6 years
Dishwasher	1
Age	4 years
Electric coffee maker	1
Microwave oven	1
Clothes washer	1
Top loaded	Yes
Age	5 years
Clothes dryer	1
Fuel source	Electric
Age	5 years
Ceiling fans in house	1
Water heater	1
Fuel source	Electric
Size	31 -49 gallons
Age	6 years

Table 4-4. Typical single family housing: furnishings

Characteristic	Quantity/Affirmation
Entertainment system	
Television	2
VCR player	1
DVD player	1
Cable or satellite dish	Yes
Video gaming system	No
Personal computer system	
Computers	1
Monitors	1 standard CRT
Internet access	Yes – cable or DSL
Printer (without fax/copy capability)	1
Stereo system	1

Table 4-5. Ceiling fan EEM performance

	Parameters		
Characteristics	Collected statistical data	Required calculation assumptions	Value
Number of existing fans	X		1
Number of Added fans		X	3
Location of fans		X	Master bedroom Guest bedroom 1 Guest bedroom 2
Increase of cooling set point	X		3 degrees
Fan size		X	48 inches
Fan power draw	X		75 Watts/hour
Duration fan in on per day		X	12 hours
Calculation			Manual/Comp simulation
Savings			434.5kWh/year $50.62/year

Table 4-6. Ceiling fan EEM cost

Energy efficiency measure:		Additional ceiling fans					
		Labor			Material		
Item	Quantity	Hours	Rate	Subtotal	Unit cost	Subtotal	Total
Ceiling fan	3	1	$49	$147	$120	$360	$506.18
Light kit	3	1	$38	$113	$26	$78	$191.25
Material tax				$0		$0.00	$32.90
Subtotal							$730.33
General conditions	5%						$36.52
Overhead & profit	15%						$115.03
Total							$881.87

Note: Professional, non-union installation.
Price source was Means Pricing Guide – Repair and Remodeling Cost 2005.
Geographic Multiplier used was .85 of national.
Fan assumed was in the Means “better quality” category.

Table 4-7. HVAC tune up (re-commissioning) EEM performance

	Parameters		
Characteristics	Collected statistical data	Required calculation assumptions	Value
HVAC system type	X		Split system
Air handler location		X	Conditioned closet
Condenser unit location		X	Outside, ground level
Number of units	X		1
Increased efficiency		X	5%
Calculation			Computer simulation
Savings			380kWh/year $44.27/year

Table 4-8. HVAC tune up (re-commissioning) EEM cost

Energy efficiency measure:		HVAC tune-up					
			Labor			Material	
Item	Quantity	Hours	Rate	Subtotal	Unit cost	Subtotal	Total
Basic tune up	1			$0	$65	$65	$65.00
Additional refrigerant	1			$0	$175	$175	$175.00
Additional repairs	1			$0	$175	$175	$175.00
Material tax				$0		$0.00	$22.75
Subtotal							$437.75
General conditions	5%						$21.89
Overhead & profit	15%						$68.95
Total							$528.58

Note: Professional, non-union installation.
Price source was Interview with Ron Bennett, owner of CCS, LLC: 352-317-3846: http://climatecontrolservicesllc.com/default.asp.
Repair included electrical check, delta T check, blower and amp draw optimization, lubricate parts, tighten belts, static pressure test and refrigerant check.

Table 4-9. Leaking HVAC ductwork EEM performance

	Parameters		
Characteristics	Collected statistical data	Required calculation assumptions	Value
Model House ductwork loss	X		20%
Reduced ductwork loss		X	10%
Calculation			Computer simulation
Savings			
			750kWh/year $87.38/year

Table 4-10. Leaking HVAC ductwork EEM cost

Energy efficiency measure:		Sealing Ductwork						
			Labor			Material		
Item	Quantity	Hours	Rate	Subtotal	Unit cost		Subtotal	Total
Diagnostics testing	1			$0	$200		$200	$200.00
Blower testing	1			$0	$200		$200	$200.00
Repair	1			$0	$850		$850	$850.00
Material tax				$0			$0.00	$68.25
Subtotal								$1,318.25
General conditions	5%							$65.91
Overhead & profit	15%							$207.62
Total								$1,591.79

Note: Professional, non-union installation.
Price source was Interview with Ron Bennett, owner of CCS, LLC: 3352-317-3846: http://climatecontrolservicesllc.com/default.asp.
Repair included pressurizing ductwork to identify leaks, torn or leaking duct repaired using mastic compound.

Table 4-11. High SEER a/c unit EEM performance

	Parameters		
Characteristics	Collected statistical data	Required calculation assumptions	Value
Existing SEER rating		X	10 SEER
New SEER rating		X	14 SEER
System type		X	Split DX with direct return
Calculation			Computer simulation
Savings			2,150kWh/year $250.48/year

Table 4-12. High SEER ac unit EEM performance

Energy efficiency measure: New high SEER AC unit

		Labor			Material		
Item	Quantity	Hours	Rate	Subtotal	Unit cost	Subtotal	Total
Compressor demo	1	1	$296.85	$296.85	$0.00	$0.00	$296.85
Compressor install	1	1	$170.85	$170.85	$552.50	$552.50	$723.35
Cond unit demo	1	1	$101.15	$101.15		$0.00	$101.15
Cond unit install	1	1	$416.50	$416.50	$777.75	$777.75	$1,194.25
Material tax				$0.00		$0.00	$150.51
Permit	1			$0.00	$210.00	$210.00	$210.00
Subtotal							$2,676.11
General conditions	5%						$133.81
Overhead & profit	15%						$421.49
Total							$3,231.41

Note: Professional, non-union installation.
Price source was Means Pricing Guide – Repair and Remodeling Cost 2005.
Geographic Multiplier used was .85 of national.
Size assumed was a 3 ton unit.

Table 4-13. Low flow shower heads and aerators EEM performance

	Parameters		
Characteristics	Collected statistical data	Required calculation assumptions	Value
Baseline hot water usage	X		28,250 gallons/year
Hot water usage with EEM		X	22,995 gallons/year
Percent reduction	X		19%
EEM used		X	Two low flow shower heads & 2 aerators
Water heater load	X		4,500wh
Electric input ratio		X	1.3
Municipal water temperature		X	75 degrees
Hot water temperature	X		120 degrees
Calculation			Manual
Savings			
			430kWh/year $50.10/year

Table 4-14. Low flow shower heads and aerators EEM cost

Energy efficiency measure:		Low flow shower heads and aerators					
		Labor			Material		
Item	Quantity	Hours	Rate	Subtotal	Unit cost	Subtotal	Total
Shower heads	2			$0	$18.96	$37.92	$37.92
Aerators	2			$0	$4.29	$8.58	$8.58
Material tax				$0		$0	$3.02
Subtotal							$49.52
General conditions	5%						n/a
Overhead & profit	15%						n/a
Total							$49.52

Note: Home owner installation.
Price source for shower head was Home Depot's ™ website 12/22/10
Shower head assumed was manufactured by Alsons © model number 654CPK.
Price source for aerator was Home Depot's ™ website 12/22/10
Aerator assumed was manufactured by Neoperl © model number 37.0084.98

Table 4-15. Solar water heating EEM performance

	Parameters		
Characteristics	Collected statistical data	Required calculation assumptions	Value
Solar water heating style		X	Medium temp unit circulating water
Draw of backup heating Elements		X	4,500wh
Circulation pump		X	Solar power
Tank size		X	120 gallon
Solar collector size		X	48sqft
Backup heating element use		X	20%
Hot water usage	X		25.8 gallons/person/day
Calculation			Computer simulation
Savings			1,810kWh/year $210.87/year

Table 4-16. Solar water heating EEM cost

Energy efficiency measure: solar water heating

		Labor			Material		
Item	Quantity	Hr	Rate	Subtotal	Unit cost	Subtotal	Total
Collector kit	1	16	$28.40	$454.40	$976.50	$976.50	$1,430.90
Tank	1	8	$28.40	$227.20	$935.00	$935.00	$1,162.20
Tank hook up	40	4	$23.05	$92.20	$3.77	$150.80	$243.00
Drainback assembly	1	8	$23.05	$184.40	$475.00	$475.00	$659.40
Mounting kit	1	8	$28.40	$227.20	$65.63	$65.63	$292.83
Shipping	1			$0.00	$373.00	$373.00	$373.00
Material tax				$0.00		$0.00	$270.49
Permit	1			$0.00	$100.00	$210.00	$210.00
Subtotal							$4,641.82
General conditions	5%						$232.09
OH&P	15%						$731.09
Total							$5,604.99

Note: Professional, non-union installation.
Price source was from EnergySupermarket.com ™.
System assumed was a Sun Earth Active Solar Water Heater Panel.
Tank size assumed was 120 gallons.
Tank and piping price source was from RS Means, 2010, Residential New Construction Pricing Guide.

Table 4-17. Window film EEM performance

Characteristics	Parameters: Collected statistical data	Parameters: Required calculation assumptions	Value
Window film location		X	All exterior windows
U Value with window		X	.99
Shading coefficient with window		X	.58
Visible light transmittance		X	.69
Calculation			Computer simulation
Savings			460kWh/year $55.59/year

Table 4-18. Window film EEM cost

Energy efficiency measure: window film

Item	Quantity	Labor: Hours	Labor: Rate	Labor: Subtotal	Material: Unit cost	Material: Subtotal	Total
Window film cleaning	15			$0	$35.61	$534.15	$534.15
Accessories	1			$0		$0.00	$0.00
Material tax				$0		$0.00	$34.72
Subtotal							$568.87
General conditions	5%						n/a
Overhead & profit	15%						n/a
Total							$568.87

Note: Home owner installation.
Price source was Home Depot's ™ website 12/22/10.
Cleaning accessories assumed were Gila Complete Window Film Application Kit ™ model number RTK500SM.

Table 4-19. Increased attic insulation EEM performance

Characteristics	Parameters: Collected statistical data	Parameters: Required calculation assumptions	Value
Original insulation value	X		R19
Increase of insulation		X	R 23 blown in insulation
Type of insulation		X	6” of blown-in insulation
Location		X	Attic floor over Existing insulation
Calculation			Computer simulation
Savings			90kWh/year $10.49/year

Table 4-20. Increased attic insulation EEM cost

Energy efficiency measure: attic insulation

		Labor			Material		
Item	Quantity	Hours	Rate	Subtotal	Unit cost	Subtotal	Total
Install insulation	1800	1	$0.20	$367.20	$0.27	$489.60	$856.80
Material tax				$0.00		$0.00	$55.69
Subtotal							$912.49
General conditions	5%						$45.62
Overhead & profit	15%						$143.72
Total							$1,101.83

Note: Professional, non-union installation.
Price source was Means Pricing Guide – Repair and Remodeling Cost 2005.
Geographic Multiplier used was .85 of national.
Insulation assumed had an R value of 23 and was 6” blown-in.

Table 4-21. Retro-foam in walls EEM performance

Characteristics	Parameters: Collected statistical data	Required calculation assumptions	Value
Reduction in air infiltration		X	30%
Calculation			Computer simulation
Savings			
			180kWh/year $20.97/year

Table 4-22. Retro-foam in walls EEM cost

Energy efficiency measure: Retro - foam in walls

Item	Quantity	Labor: Hours	Rate	Subtotal	Material: Unit cost	Subtotal	Total
Foam Subcontractor	1984			$0.00	$2.50	$4,960.00	$4,960.00
Finish repair	1	16	$34.54	$552.57	$100.00	$100.00	$652.57
Material tax				$0.00		$0.00	$364.82
Subtotal							$5,977.38
General conditions	5%						$298.87
Overhead & profit	15%						$941.44
Total							$7,217.69

Note: Professional, non-union installation.
Price source was Total Comfort Installation, LLC from Jacksonville, FL.
Material used was spray polyurethane foam.

Table 4-23. Low-E glass EEM performance

Characteristics	Parameters: Collected statistical data	Parameters: Required calculation assumptions	Value
Baseline window type		X	Single clear 1/8” glass frame without breaks
New window type		X	Double Low-E (e3 = .2) ¼” glass with ½” air gap. Frame with insulated break
Window/Floor space	X		15%
Calculation			Computer simulation
Savings			
			440kWh/year
			$51.26/year

Table 4-24. Low-E glass EEM cost

Energy efficiency measure: Low-E window replacement

		Labor			Material		
Item	Quantity	Hours	Rate	Subtotal	Unit cost	Subtotal	Total
Windows	6	1	$81.05	$486.29	$276.25	$1,657.50	$2,143.79
Sliding glass door	2	1	$223.13	$446.25	$531.25	$1,062.50	$1,508.75
Finish repair	8	2	$34.53	$552.50	$10.00	$80.00	$632.50
Material tax				$0.00		$0.00	$182.00
Permit	1			$0.00	$210.00	$210.00	$210.00
Subtotal							$4,677.04
General conditions	5%						$233.85
Overhead & profit	15%						$736.63
Total							$5,647.52

Note: Professional, non-union installation.
Price source was Means Pricing Guide – Repair and Remodeling Cost 2005.
Geographic Multiplier used was .85 of national.
Window assumed was a double hung, two light double glazed aluminum window with screen.
Sliding glass door assumed was an insulated door with an aluminum frame.

Table 4-25. Awning EEM performance

Characteristics	Parameters: Collected statistical data	Parameters: Required calculation assumptions	Value
Elevation overhangs located		X	East elevation West elevation South elevation
Depth of overhang		X	3 feet
Overhang type		X	Fabric over aluminum frame
Calculation			Computer simulation
Savings			550kWh/year $64.08/year

Table 4-26. Awning EEM cost

Energy efficiency measure: awnings over openings

		Labor			Material		
Item	Quantity	Hours	Rate	Subtotal	Unit cost	Subtotal	Total
Window awning	4	1.00	$27.63	$110.50	$165.75	$663.00	$773.50
Sliding glass door	64	1.00	$2.77	$177.34	$5.70	$364.48	$541.82
Material tax				$0.00		$0.00	$85.50
Subtotal							$1,400.82
General conditions	5%						$70.04
Overhead & profit	15%						$220.63
Total							$1,691.49

Note: Professional, non-union installation.
Price source was Means Pricing Guide – Repair and Remodeling Cost 2005.
Geographic Multiplier used was .85 of national.
Window awning assumed was a 48”x30” aluminum awning with weather resistant finish.
Sliding glass awing assumed was a roll up type.

Table 4-27. Skylight EEM performance

Characteristics	Parameters Collected statistical data	 Required calculation assumptions	Value
Size of skylights		X	4'-0" x 4'-0" nominal
Location		X	Dining room Living room
Light well depth		X	5'-0"
Skylight construction		X	Dome aluminum frame with breaks and double acrylic glazing
Calculation			Computer simulation
Savings			Negative 100kWh/year Negative $11.65/year

Table 4-28. Skylight EEM cost

Energy efficiency measure: skylight

		Labor			Material		
Item	Quantity	Hours	Rate	Subtotal	Unit cost	Subtotal	Total
Skylight	2	1	$83.73	$167.45	$293.25	$586.50	$753.95
Demo/Protection	2	3.3	$34.53	$227.91	$15.00	$30.00	$257.91
Light well framing	2	4	$34.53	$276.25	$75.00	$150.00	$426.25
Light well Drywall	2	3	$34.53	$207.19	$45.00	$90.00	$297.19
Light well finishing	2	2.5	$34.53	$172.66	$15.00	$30.00	$202.66
Roof fepair	2	1	$127.50	$255.00	$61.20	$122.40	$377.40
Material tax				$0.00		$0.00	$57.62
Permit	1			$0.00	$110.00	$110.00	$110.00
Subtotal							$2,482.97
General conditions	5%						$124.15
Overhead & profit	15%						$391.07
Total							$2,998.19

Note: Professional, non-union installation.
Price source was Means Pricing Guide – Repair and Remodeling Cost 2005.
Geographic Multiplier used was .85 of national.
Skylight was 44"x46" and operable with a 5' lightwell. Finish was painted drywall.

Table 4-29. Strategically placed landscaping EEM performance

Characteristics	Parameters Collected statistical data	Required calculation assumptions	Value
Number of existing shading trees	X		0
Number of trees added		X	2
Location		X	East & West Elevation
Trees species		X	Red Maple – 16’ in height with 3” diameter truck.
Reduction in solar load at east and west windows		X	50%
Calculation			Computer simulation
Savings			100kWh/year $11.65/year

Table 4-30. Strategically placed landscaping EEM cost

Energy efficiency measure: Strategically placed landscaping

Item	Quantity	Labor Hours	Rate	Subtotal	Material Unit cost	Subtotal	Total
Red maple 16' (3" caliper)	2	3.2	$20.99	$134.36	$298.43	$596.86	$731.22
Tree guying	2	0.457	$19.06	$17.42	$16.46	$32.92	$50.34
3" aged bark mulch	2	0.08	$17.19	$2.75	$0.76	$1.52	$4.27
Delivery	1				$50.00	$50.00	$50.00
Material tax							$54.33
Subtotal							$890.16
General conditions	5%						$44.51
Overhead &profit	15%						$140.20
Total							$1,074.87

Note: Professional, non-union installation.
Price source was RS Means Cost Works Residential New Construction 2010.
Geographic Multiplier used was .85 of national.
Delivery cost was an estimated assumption for residential retrofit work.

Table 4-31. Compact fluorescent lighting EEM performance

Characteristics	Parameters: Collected statistical Data	Parameters: Required calculation assumptions	Value
Number of replaced lights		X	27 bulbs
Original bulb draw		X	60 Watt
CFL bulb draw		X	14 Watts
Average lighting level		X	12 foot-candles'
Average CFL light output		X	800 lumens
Calculation			Computer simulation
Savings			
			4,080kWh/year
			$475.32/year

Table 4-32. Compact fluorescent lighting EEM cost

Energy efficiency measure: compact fluorescent light replacement

		Labor			Material		
Item	Quantity	Hours	Rate	Subtotal	Unit cost	Subtotal	Total
CFL bulbs (4 pack)	7			$0	$8	$56	$55.79
Material tax				$0		$0	$3.63
Subtotal							$59.42
General conditions	5%						n/a
Overhead & profit	15%						n/a
Total							$59.42

Note: Home owner installation.
Price source was Home Depot ™ website on 12/22/10.
Bulb assumed was a EcoSmart ™, 14W Daylight CFL (4 pack)
Assumed bulb model number was ES5M814450K
Fan assumed was in the Means "better quality" category.
Pricing does not include allowance for replacements if new lamps are damaged.

Table 4-33. LED lighting EEM performance

Characteristics	Parameters Collected statistical data	 Required calculation assumptions	Value
Number of LED lights		X	43 bulbs
Number of original incandescent bulbs		X	27 bulbs
Original bulb draw		X	60 Watt
LED bulb draw		X	8.5 Watts
Average lighting level		X	12 foot-candles'
Average LED light output		X	510 warm light lumens
Original incandescent bulb light output		X	800 warm light lumens
Calculation			Computer simulation
Savings			4,130kWh/year $481.15/year

Table 4-34. LED lighting EEM cost

Energy efficiency measure: LED lighting replacement

Item	Quant.	Labor Hours	 Rate	 Subtotal	Material Unit cost	 Subtotal	Total
LED bulbs	43			$0	$45.95	$1,975.85	$1,975.85
Material tax				$0		$0	$128.43.55
Subtotal							$2,104.28
General conditions	5%						n/a
Overhead/profit	15%						n/a
Total							$2,104.28

Note: Home owner installation.
Price source was from LED Wave ™ website.
Blub assumed was a Mark II ™ (A19-A60) incandescent replacement LED.
Pricing does not include allowance for replacements if new lamps are damaged.

Table 4-35. ES clothes washer EEM performance

Characteristics	Parameters Collected statistical data	 Required calculation assumptions	Value
Clothes washer use		X	4 loads per week
Loads using hot water		X	2 loads per week
Energy Star ™ reduction in electricity		X	30%
Energy Star ™ reduction in water		X	50%
Traditional unit electricity use	X		1.242kWh/load
Traditional unit water use	X		31.07gallons/load
Calculation			Manual
Savings			255.46kWh/year $29.76/year

Table 4-36. ES clothes washer EEM cost

Energy efficiency measure: Energy Star ™ clothes washer

Item	Quantity	Labor Hours	 Rate	 Subtotal	Material Unit cost	 Subtotal	Total
Clothes dryer	1			$0.00	$539.10	$539.10	$539.10
Delivery/Install	1			$0.00	$50.00	$50.00	$50.00
Material tax				$0.00		$0.00	$38.29
Subtotal							$627.39
General conditions	5%						n/a
Overhead &profit	15%						n/a
Total							$627.39

Note: Home owner installation.
Price source was Home Depot's ™ website 12/22/10.
Washer assumed was a Maytag Bravos X ™ (4.3 cuft).

Table 4-37. Energy Star ™ refrigerator EEM performance

Characteristics	Parameters: Collected statistical data	Parameters: Required calculation assumptions	Value
Refrigerator style	X		Top bottom door
Size	X		15 – 18cuft
Average energy use	X		529kWh/year
Reduced energy with Energy Star	X		20% reduction
Calculation			Manual
Savings			105.8kWh/year $12.33/year

Table 4-38. Energy Star ™ refrigerator EEM cost

Energy efficiency measure: Energy Star ™ refrigerator

		Labor			Material		
Item	Quantity	Hours	Rate	Subtotal	Unit cost	Subtotal	Total
Refrigerator	1			$0.00	$619.10	$619.10	$619.10
Delivery/Install	1			$0.00	$50.00	$50.00	$50.00
Material tax				$0.00		$0.00	$43.49
Subtotal							$712.59
General conditions	5%						n/a
Overhead & profit	15%						n/a
Total							$712.59

Note: Home owner installation.
Price source was Home Depot's ™ website 12/22/10.
Refrigerator assumed was a Maytag ™ 21.0cuflt top freezer refrigerator model (M1TXEMMWW).

Table 4-39. Energy Star ™ dishwasher EEM performance

Characteristics	Parameters Collected statistical data	Required calculation assumptions	Value
Dishwasher loads per week	X		4.13 loads/week
Traditional unit electricity use	X		1.33kWh/cycle
Traditional unit hot water use	X		4 gallons/cycle
Energy Star ™ electricity use	X		1.67kWh/cycle
Energy Star ™ hot water use	X		6 gallons / cycle
Calculation			Manual
Savings			
			120.32kWh/year
			$14.02/year

Table 4-40. Energy Star ™ dishwasher EEM cost

Energy efficiency measure: Energy Star ™ dishwasher

		Labor			Material		
Item	Quantity	Hours	Rate	Subtotal	Unit cost	Subtotal	Total
Dishwasher	1			$0.00	$404.10	$404.10	$404.10
Delivery/Install	1			$0.00	$112.00	$112.00	$112.00
Material tax				$0.00		$0.00	$33.55
Subtotal							$549.65
General conditions	5%						n/a
Overhead & profit	15%						n/a
Total							$549.65

Note: Home owner installation.
Price source was Home Depot's ™ website 12/22/10.
Dishwasher assumed was a Maytag JetClean Plus ™ built-in tall tub model number MDBH969AWW.

Table 4-41. Stand-by power loss EEM performance

Characteristics	Parameters: Collected statistical data	Required calculation assumptions	Value
Number of appliances	X		5 units
Number of power interrupters		X	2 units
Appliance types	X		Television VCR Cable box PC monitor PC printer
Average standby power draw		X	10 Watts
Time turned off & not in standby		X	8 hours/day
Calculation			Manual
Savings			146kWh/year $17.01/year

Table 4-42. Stand-by power loss EEM cost

Energy efficiency measure: reduce standby power loss

Item	Quantity	Labor: Hours	Rate	Subtotal	Material: Unit cost	Subtotal	Total
Power interrupters	2			$0	$9.95	$20	$19.90
Shipping	2			$0	$7.95	$16	$15.90
Material tax				$0		$0	$2.33
Subtotal							$38.13
General conditions	5%						n/a
Overhead & profit	15%						n/a
Total							$38.13

Note: Home owner installation.
Price source was www.asseenontv.com.
Device assumed was the Handi Switch.

Table 4-43. Programmable thermostat EEM performance

Characteristics	Parameters: Collected statistical data	Parameters: Required calculation assumptions	Value
Number of HVAC units		X	1 unit
Temp set in warm months	X		76 degrees
Temp set in cool months	X		65 degrees
Temp set back in warm months		X	7 degrees
Temp set back in cool months		X	8 degrees
Set back schedule		X	9:00am – 5:00pm M-F
Calculation			Computer simulation
Savings			1,380kWh/year $160.77/year

Table 4-44. Programmable thermostat EEM cost

Energy efficiency measure: programmable thermostat

Item	Quantity	Labor: Hours	Labor: Rate	Labor: Subtotal	Material: Unit cost	Material: Subtotal	Total
Programmable T-Stat	1	1	$38	$38	$168.56	$168.56	$206.39
Material tax				$0		$0.00	$13.42
Subtotal							$219.80
General conditions	5%						$10.99
Overhead & profit	15%						$34.62
Total							$265.41

Note: Professional, non-union installation.
Price source was Means Pricing Guide – Repair and Remodeling Cost 2005.
Geographic Multiplier used was .85 of national.
Thermostat assumed as 2 set point capability.

Table 4-45. Occupancy sensor EEM performance

Characteristics	Parameters: Collected statistical data	Parameters: Required calculation assumptions	Value
Lighting power intensity		X	.9 Watts/sqft
Number of OS installed		X	6
Rooms OS installed		X	Master bedroom East bedroom West bedroom Kitchen Dining room Living room
Reduction from ineffective lighting		X	10%
Calculation			Computer simulation
Savings			440kWh/year $51.26/year

Table 4-46. Occupancy sensor EEM cost

Energy efficiency measure: Occupancy Sensor

		Labor			Material		
Item	Quantity	Hours	Rate	Subtotal	Unit cost	Subtotal	Total
Occupancy Sensors	6	1	$17.77	$107	$39.99	$239.94	$346.53
Plate	6	1	$3.78	$23	$0.29	$1.73	$24.43
Material tax				$0		$0.00	$22.52
Subtotal							$393.48
General conditions	5%						$19.67
Overhead & profit	15%						$61.97
Total							$475.13

Note: Professional, non-union installation.
Price source for install is Means Pricing Guide – Repair and Remodeling Cost 2005.
Geographic Multiplier used was .85 of national.
Occupancy sensor assumed was a Lutron Maestro™ with Eco-dim.
Price source for occupancy sensor from Home Depot's ™ website 12/22/11.

Table 4-47. Energy dashboards EEM performance

Characteristics	Parameters: Collected statistical data	Parameters: Required calculation assumptions	Value
System components		X	1 central monitoring station 1 main panel transmitter 4 plug in transmitters 5 hard wire CT transmitters
Location of individual Appliance monitor		X	1 computer area 1 entertainment center
Location of hard wire Transmitters		X	1 water heater 1 HVAC 1 oven 1 dryer
Reduction in consumer demand	X		10%
Calculation			Computer simulation
Savings			2,270kWh/year $264.46/year

Table 4-48. Energy dashboard EEM cost

Energy efficiency measure:	energy monitoring dashboard						
		Labor			Material		
Item	Quantity	Hours	Rate	Subtotal	Unit cost	Subtotal	Total
Display and whole house transmitter	1	1	$37.72	$38	129.00	$129	$166.72
Additional 208 CT monitor	4	2	$37.72	$302	79.00	$316	$617.75
Additional individual appliance monitor	2	0.25	$37.72	$19	79.00	$158	$176.86
Material tax				$0		$0.00	$51.65
Shipping	1			$0	24.75	$25	$24.75
Subtotal							$1,012.98
General conditions	5%						$50.65
Overhead & profit	15%						$159.54
Total							$1,223.17

Note: Professional, non-union installation.
Price source was Power Save website 12/29/10.
Energy monitor assumed was the Envi ™ by Power Saver Inc.
Fan assumed was in the Means "better quality" category.

Table 4-49. Photovoltaic EEM performance

	Parameters		
Characteristics	Collected statistical data	Required calculation assumptions	Value
Photovoltaic array size		X	8'x15' (hxw)
Average length of direct sun		X	4.5 hours per day
Array's electrical output		X	10 Watts/sqft/hour
Calculation			Manual
Savings			1,971kWh/year $229.62/year

Table 4-50. Photovoltaic EEM cost

Energy efficiency measure: photovoltaic panel array

		Labor			Material		
Item	Quantity	Hours	Rate	Subtotal	Unit cost	Subtotal	Total
PV panels	1	10	$32.68	$326.80	$5,550.00	$5,550.00	$5,876.80
AC/DC inverter	1	2	$32.89	$65.78	$1,500.00	$1,500.00	$1,565.78
Material tax				$0.00		$0.00	$458.25
Permit	1			$0.00	$210.00	$210.00	$210.00
Subtotal							$8,110.83
General conditions	5%						$405.54
Overhead & profit	15%						$1,277.46
Total							$9,793.83

Note: Professional, non-union installation.
Price source was Means Pricing Guide 2010 Cost Data for New Commercial Construction.
Geographic Multiplier used was .85 of national.

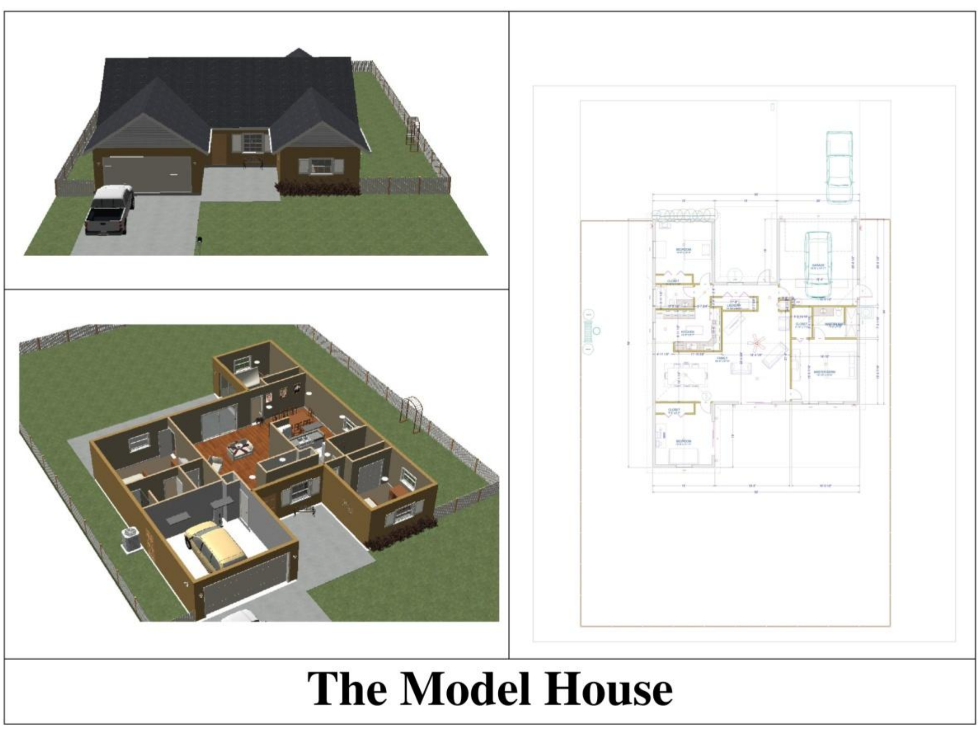


Figure 4-1. The Model House.

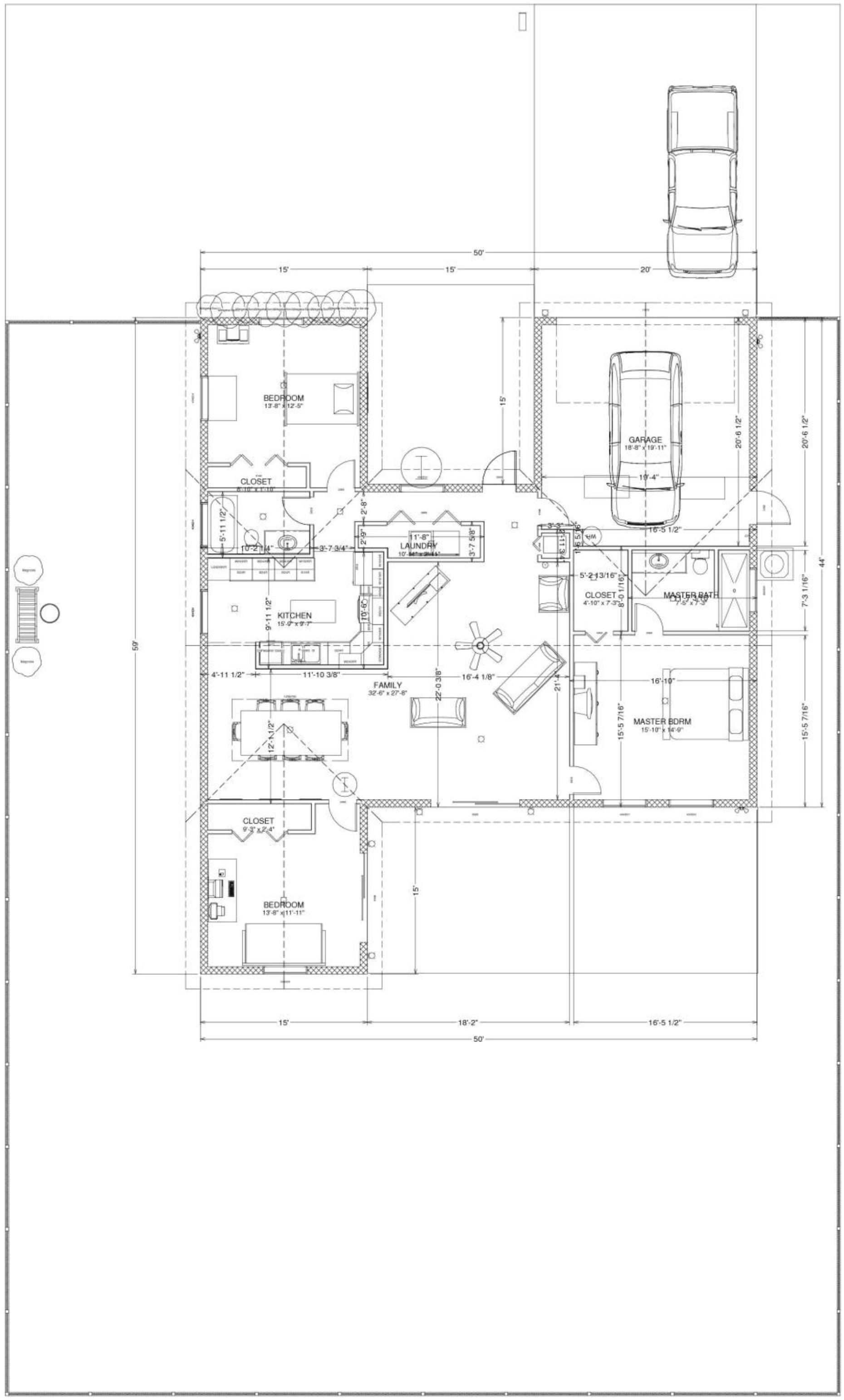


Figure 4-2. Floor Plan of Model House.

Figure 4-3. Living Room of Model House.

Figure 4-4. Kitchen of Model House.

Figure 4-5. West Bedroom of Model House.

Figure 4-6. Master Bedroom.

Figure 4-7. Back Yard Patio.

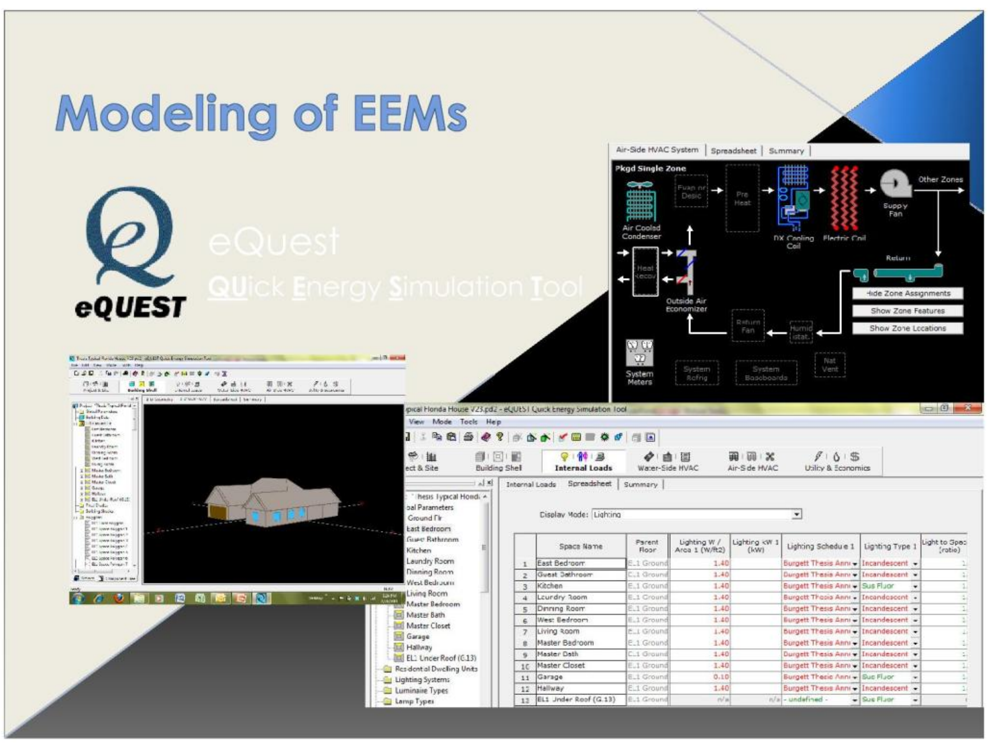


Figure 4-8. eQUEST - Introduction.

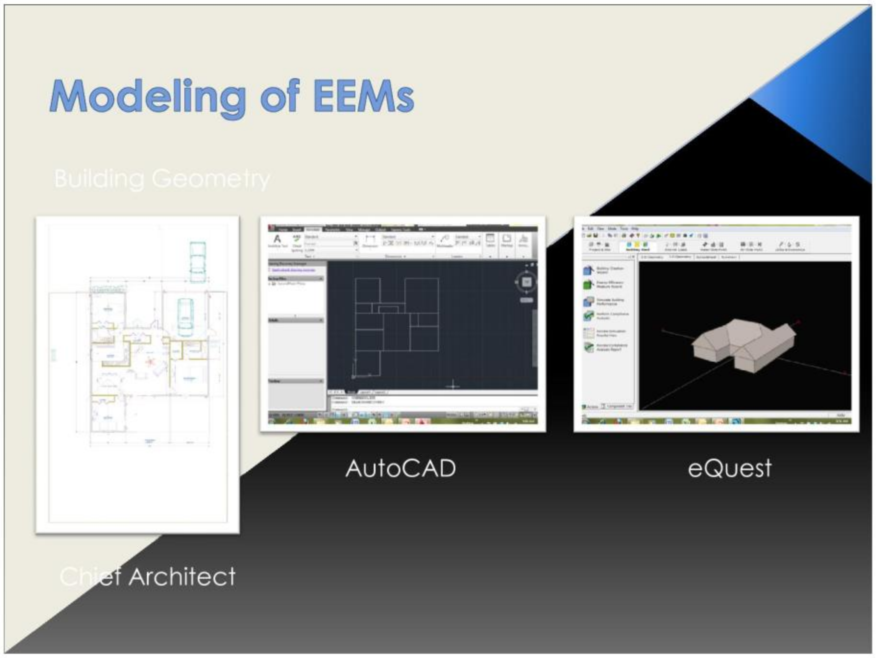


Figure 4-9. eQUEST – Building Geometry.

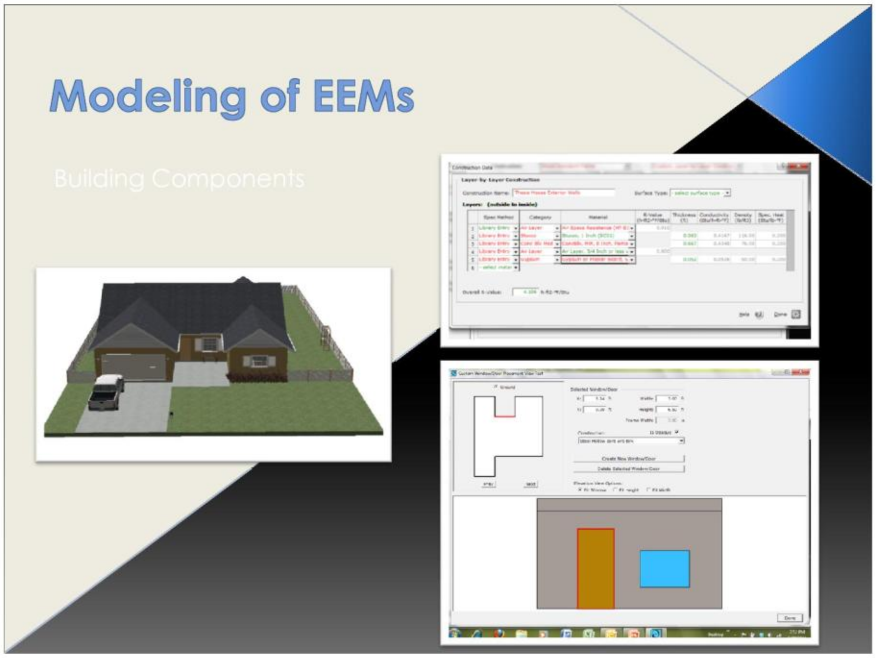


Figure 4-10. eQUEST – Building Components.

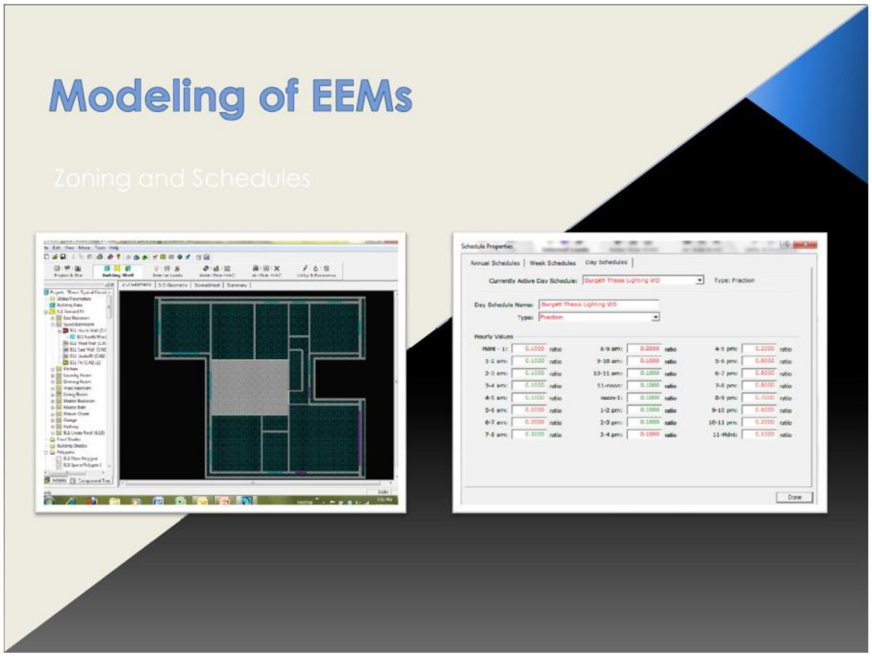


Figure 4-11. eQUEST – Zoning and Schedules.

CHAPTER 5
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The focus of this research was to identify common energy efficiency measures and test their effectiveness on typical Florida housing. To test the effectiveness a computer simulated house was created that shared characteristics most common to Florida single family homes. This research called the computer simulation the Model House. Effectiveness was defined by two components; cost and savings. Cost was measured by the initial influx of capital expense required to apply the measure to the Model House. Savings was measured by determining the yearly consumption of energy after an EEM was applied and comparing it to the Model House's baseline energy use.

Matrix of Results

The Matrix of Results is a table that includes the raw data collected from the study and can be found in Table 5-1. The graphs that follow pull their information from this matrix and show trends in the data. However, before the data can be analyzed it is important to fully understand what the columns represent.

- Capital Cost: The capital cost represents the initial influx of financial resources to implement the EEM. The column values are cost estimates calculated by performing a quantity take-off, applying unit costs and adding appropriate mark-ups. The summary of these estimates can be found in the tables at the end of chapter four. An example of the cost estimate for the additional ceiling fan EEM can be found in Table 4-6.

- Kilowatt Saved: The kilowatt saved column is the quantity of energy reduced per year when the EEM is applied to the Model House. The Model House's baseline energy use can be found in Appendix A. The summary of energy reduced with the assumptions made can be found in the tables at the end of chapter four. An example of the kilowatts saved for the additional ceiling fan EEM can be found in Table 4-5.

- Savings from EEM/year: This column represents in financial terms the value of the conserved energy. The average cost of electrical energy in Florida is $.1165 per kWh. The additional ceiling fan EEM for example reduces the energy use by 435kWh per year.

By multiplying the energy saved by the average energy cost (435kWh * $.1165/kWh) you can see the yearly energy savings in financial terms ($50.68).

- Gross ROI Time: This column calculates the number of years required for the "Savings from EEM/year" to cumulatively equal the value of the "Capital Cost". The calculation is performed by dividing the "Capital Cost" column by the "Savings from EEM/year" column. For the additional ceiling fan EEM the calculation would be $882/$50.68.

- Competing Investment Rate: This study evaluates the EEMs in terms of investment returns. However, to determine if an EEM is a favorable investment there must be a set value that represents the estimated return of competing investments. In a report published by the Florida Solar Energy Center a rate of eight percent was used as the minimum expected return for a favorable EEM investment (Fairey & Vieira 2009). This value was computed by taking the guaranteed return from the State of Florida DROPS retirement account and adding an additional 1.5%. This study will use the same expected return value in its analysis.

- EEM ROI: This column is the gross return on investment from each of the EEMs. The calculation is the division of the "Savings from EEM/year" column by the "Capital Cost" column. For the additional ceiling fan EEM it would be $50.68/$882 which equal 5.75%. The percentage represents the return on an annual basis.

- Return Above Competing Investments: This column is the determination of whether an EEM is considered a favorable investment. The "Return Above Competing Investments" column takes the "EEM ROI" column and subtracts the eight percent return of competing investments as shown in the "Competing Investment Rate" column. If the resulting value is positive, then the value represents the percent return the EEM will earn above the competing investments and is considered favorable. If the value is negative, then the EEM will generate a return less than that of competing investments and is considered unfavorable. In the case of the additional ceiling fan EEM, the EEM ROI of 5.75% is subtracted by the assumed competing investment return of eight percent resulting in an unfavorable investment of 2.25% lower than other investment options.

- Net ROI Time: The "Net ROI Time" column is similar to the "Gross ROI Time" column however the rate of return of competing investments is considered. With traditional investments at the end of the investment period the investor receives the interest earned plus the original principle. For EEM the original principle is converted to a fixed asset and will not be converted back to cash at the end of the investment period. This column calculates the length of time it will take the EEM to return the original principle investment (initial capital cost) while still providing interest (savings from EEM/year) at the same rate of competing investments. In the case of the additional ceiling fan EEM, the return is less than eight percent so this EEM will never return its initial capital cost. For the LED lighting EEM however, this column calculates the time required for the 14.87% ROI above competing investments to accumulate to the initial capital cost of $2,104. The calculation is capital cost divided by the capital cost * return above competing investments [2,104/(2,104*.1487)]. Some of the EEM do not have returns above the assumed eight percent of competing investments and will never return their initial principle (Capital Cost). These unfavorable investments are labeled as “none” for their Net ROI Time value.

- Cost/Kilowatt Saved: This column provides information on what the capital cost is to save one kilowatt per year. The calculation is dividing the “Capital Cost” column by the “Kilowatt Saved” column with the resulting measurement in years. For the additional ceiling fan EEM, the capital cost of $882 is divided by the kilowatt saved of 435kWh/year resulting in a cost of $2.03/kWh saved each year.

Cost vs. Savings Comparison

An important analysis of the findings is to compare the capital cost with the energy savings. As defined earlier the capital cost is the initial investment of financial resources to implement the EEM. Figure 5-1 ranks the EEM by their initial capital cost. The savings is illustrated in Figure 5-2 and ranks the EEM by the total kilowatts saved per year. The savings can also be represented in financial terms by the amount of kilowatts saved multiplied by the cost of the kilowatt. The comparison of initial capital cost and energy cost savings can be found in Figure 5-3. In this comparison there is not a direct relationship between capital expense and energy savings. To illustrate, the retro-foam and stand-by power loss EEMs have nearly the same energy savings however the retro-foam initial capital cost is $7,218 as compared to only $38 from the stand-by power loss EEM. Another way of evaluating the cost benefit of the EEM is by reviewing the cost per kilowatt conserved. Figure 5-4 provides an illustration of this by indicating the influx of capital cost required to save one kilowatt-hour each year. The cost per kilowatt chart provides a means of prioritizing which EEM will have the most effect for the least initial cost.

Return on Investment

The comparison between an EEM and a traditional investment is a close but not perfect analogy. When investing in traditional investments at the end of the investment period the investor expects to receive a cash payout equal to the interest earned plus principle. For an EEM investment the initial principle or capital cost in transferred into a fixed asset. In theory however, when the home owner sells their house they will be able to convert the initial investment back into cash through the higher selling price of the improved property. Despite this imperfect comparison, using tools to evaluate traditional investment are often the same as when evaluating an EEM. Figure 5-5 provides a graphical representation of the rate of return from each of the tested EEMs. Similar to traditional investments the EEM's return on investments is calculated on an annual basis. The computation is made by dividing the savings the EEM has per year by the initial capital expense. For this simulation it is assumed that the home owner's competing investment options yield an average return of eight percent. The EEMs that have a return of less than eight percent would be considered less favorable investments than these other traditional investment options. Competing investment options is an important factor in reviewing the net return on investment duration as show in Figure 5-6. In this chart the time it will take for the EEM to pay for itself (initial capital cost) and the savings equal to competing investments is calculated. Many of these EEM are not financially viable as their savings do not equal the return from competing investment options. Some of the EEM like window films and occupancy sensors do have savings above the competing investment rate however it will take longer to return their initial capital cost than the life span of the EEM.

Most Favorable EEM Investments

As shown in Figure 5-5, there are six EEMs that stand out as having the highest rate of return. These top six measures all have returns above 20% which is twice the return of the next closest EEM. The bullets below will list these most favorable EEM investments and explain the drivers leading to their high returns.

- CFL Replacement: This EEM has a return on investment of 800% and is the largest return by percentage of capital cost of all of the studied EEMs. This high return is due to its low cost to implement and high energy savings. Of the EEMs studied, the CFL replacement measure has the third lowest cost and the second highest energy reduction. The measure is an excellent illustration that there is not a direct relationship between initial capital cost and energy reduction.

- Low Flow Water Fixtures: This EEM has a return on investment of 101%. Although the actual kilowatts saved are close to the median, the capital cost is very low. The low capital cost is the driver behind the high rate of return.

- Programmable Thermostat: This EEM has a rate of return of 61%. The favorable return is due to a fairly strong reduction in energy and also its low cost to implement. Of the EEM tested, this measure has the fourth lowest capital cost.

- Reduction of Stand-by Power Loss: This EEM has a return of 45%. Although there is high rate of return, the driver of this percentage is the low capital cost to implement. The overall energy savings is only 146kWh or a savings of $17.01 per year.

- LED Lighting: This EEM has rate of return of 23%. The high rate of return is due primarily to the high energy savings. Of all of the EEM tested this measure has the highest reduction in energy use. Stated another way, although there are other EEM with high return percentages this EEM will reduce utility cost more than any other measure tested.

- Energy Dashboard: This EEM has a rate of return of 22%. The initial capital cost is slightly above the median EEM tested however the energy savings is the third highest. The large energy savings drives the high rate of return for this measure.

The residential market consumes nearly 40% of all domestic electrical energy. Within that market the existing home stock represents over 99% of the homes. There are numerous ways in which to lower energy consumption however barriers still exist that keep home owners from acting. The energy retrofit market is low hanging fruit that should not be ignored to improve our national economic efficiency and global climate responsibility.

Limitations

It is important to note that the most significant limitation for the research is that it attempted to define "typical" housing. The Model House used characteristics common to Florida house but there are a near infinite number of combinations of these characteristics. It is impossible to simulate all Florida houses with a single model. In addition to construction, the Model House also simulated occupant behavior. However, there again it is impossible to simulate all scenarios with a single model. The findings can provide expected results and order of magnitudes however the data must be extrapolated when applied to any real world situation.

Recommendations for Future Study

This study provides valuable information in the field of residential energy conservation, however there are several areas the research does not explore and are recommended for future study.

As there are many combinations of housing characteristics and occupant behavior it is recommended that additional models with different combinations of characteristics be created. To maximize the effectiveness of the additional models, a sensitivity study is recommended. The study should look at characteristics of the Model House and energy modeling assumptions to determine which of these characteristics have the most impact. With this information, new models could be created to specifically target these high impact areas. Specific areas that may be of interest are energy cost, number of occupants, house size, and climate differences in the hot/humid zone.

Different housing types should be reviewed for future study. This research is exclusive to single family detached houses but ignores multifamily complexes, rental units, and manufactured homes.

A study of EEM effectiveness on different economic groups may provide interesting results. Preliminary studies have shown that low income households are disproportionately burdened with high utility cost.

A review of additional EEMs both established and cut edge would benefit this field of study.

The energy savings provided by multiple EEMs applied together may not be cumulative. Competing EEMs like a super efficient water heater and a solar water heater when applied together would not have the aggregate savings as each applied independently. There would be value in researching the effectiveness of groups or packages of EEMs. Studying which EEMs complement each other and provide the highest effectiveness in combination would be valuable research.

This study provides a very simplified approach when comparing the EEMs and other investments. For example, the interest earned on traditional investments is taxed however the savings of energy (or money not spent) is not. There would be value in an advanced review of the financial impacts of the savings over extended periods of times. Items not included in this study but would be of benefit in future research include life spans of the EEM, inflation rates, net present value of energy savings, future value of initial capital cost and decreased return/efficiency on EEM over time.

Table 5-1. Matrix of Results

Matrix of Results

EEM Category	EEM	Capital Cost	Kilowatt Saved	Savings from EEM/year	Gross ROI Time (per year)	Competing Investment Rate	EEM ROI	Return Above Competing Investment	Net ROI Time (per year)	Cost/Kilowatt Save
Space Conditioning	Additional Ceiling Fans	$882	435	$50.68	17.40	8.00%	5.75%	-2.25%	none	$2.03
Space Conditioning	HVAC Tune-Up	$529	380	$44.27	11.94	8.00%	8.38%	0.38%	none	$1.39
Space Conditioning	Sealing Ductwork	$1,592	750	$87.38	18.22	8.00%	5.49%	-2.51%	none	$2.12
Space Conditioning	New High SEER AC Unit	$3,231	2150	$250.48	12.90	8.00%	7.75%	-0.25%	none	$1.50
Hot Water	Low Flow Shower Heads and Aerators	$50	430	$50.10	0.99	8.00%	101.16%	93.16%	1.1	$0.12
Hot Water	Solar Water Heating	$5,605	1810	$210.87	26.58	8.00%	3.76%	-4.24%	none	$3.10
Enclosures	Window Film	$569	460	$53.59	10.62	8.00%	9.42%	1.42%	70.4	$1.24
Enclosures	Attic Insulation	$1,102	90	$10.49	105.09	8.00%	0.95%	-7.05%	none	$12.24
Enclosures	Retro - Foam Insulation in Walls	$7,218	180	$20.97	344.19	8.00%	0.29%	-7.71%	none	$40.10
Enclosures	Low-E Window Replacement	$5,648	440	$51.26	110.17	8.00%	0.91%	-7.09%	none	$12.84
Enclosures	Awnings Over Openings	$1,691	550	$64.08	26.40	8.00%	3.79%	-4.21%	none	$3.08
Enclosures	Skylight	$2,998	-100	-$11.65	-257.36	8.00%	-0.39%	-8.39%	none	($29.98)
Enclosures	Stratigically Placed Landscaping	$1,075	100	$11.65	92.26	8.00%	1.08%	-6.92%	none	$10.75
Lighting/Appliances	Compact Fluorescent Light Replacement	$59	4080	$475.32	0.13	8.00%	799.98%	791.98%	0.1	$0.01
Lighting/Appliances	LED Lighting Replacement	$2,104	4130	$481.15	4.37	8.00%	22.87%	14.87%	6.7	$0.51
Lighting/Appliances	Energy Star Clothes Washer	$627	219	$25.51	24.59	8.00%	4.07%	-3.93%	none	$2.86
Lighting/Appliances	Energy Star Refrigerator	$713	106	$12.35	57.70	8.00%	1.73%	-6.27%	none	$6.72
Lighting/Appliances	Energy Star Dishwasher	$550	111	$12.93	42.50	8.00%	2.35%	-5.65%	none	$4.95
Home Energy Management	Reduce Standby Power Loss	$38	146	$17.01	2.24	8.00%	44.61%	36.61%	2.7	$0.26
Home Energy Management	Programmable Thermostat	$265	1380	$160.77	1.65	8.00%	60.57%	52.57%	1.9	$0.19
Home Energy Management	Occupancy Sensor	$475	440	$51.26	9.27	8.00%	10.79%	2.79%	35.9	$1.08
Home Energy Management	Energy Monitoring Dashboard	$1,223	2270	$264.46	4.63	8.00%	21.62%	13.62%	7.3	$0.54
Home Energy Management	Photovoltaic Panel Array	$9,794	1971	$229.62	42.65	8.00%	2.34%	-5.66%	none	$4.97

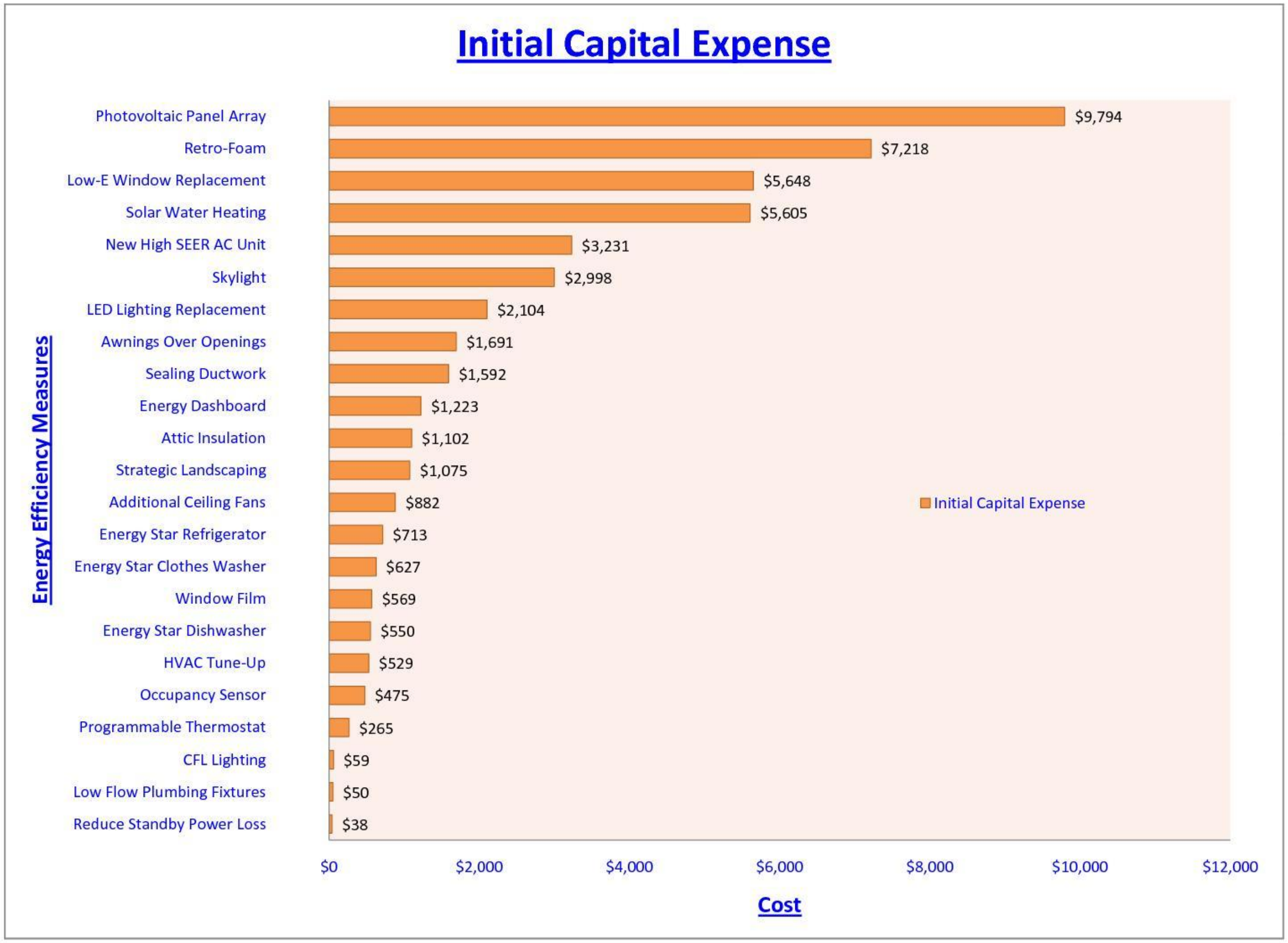


Figure 5-1. Initial Capital Expense.

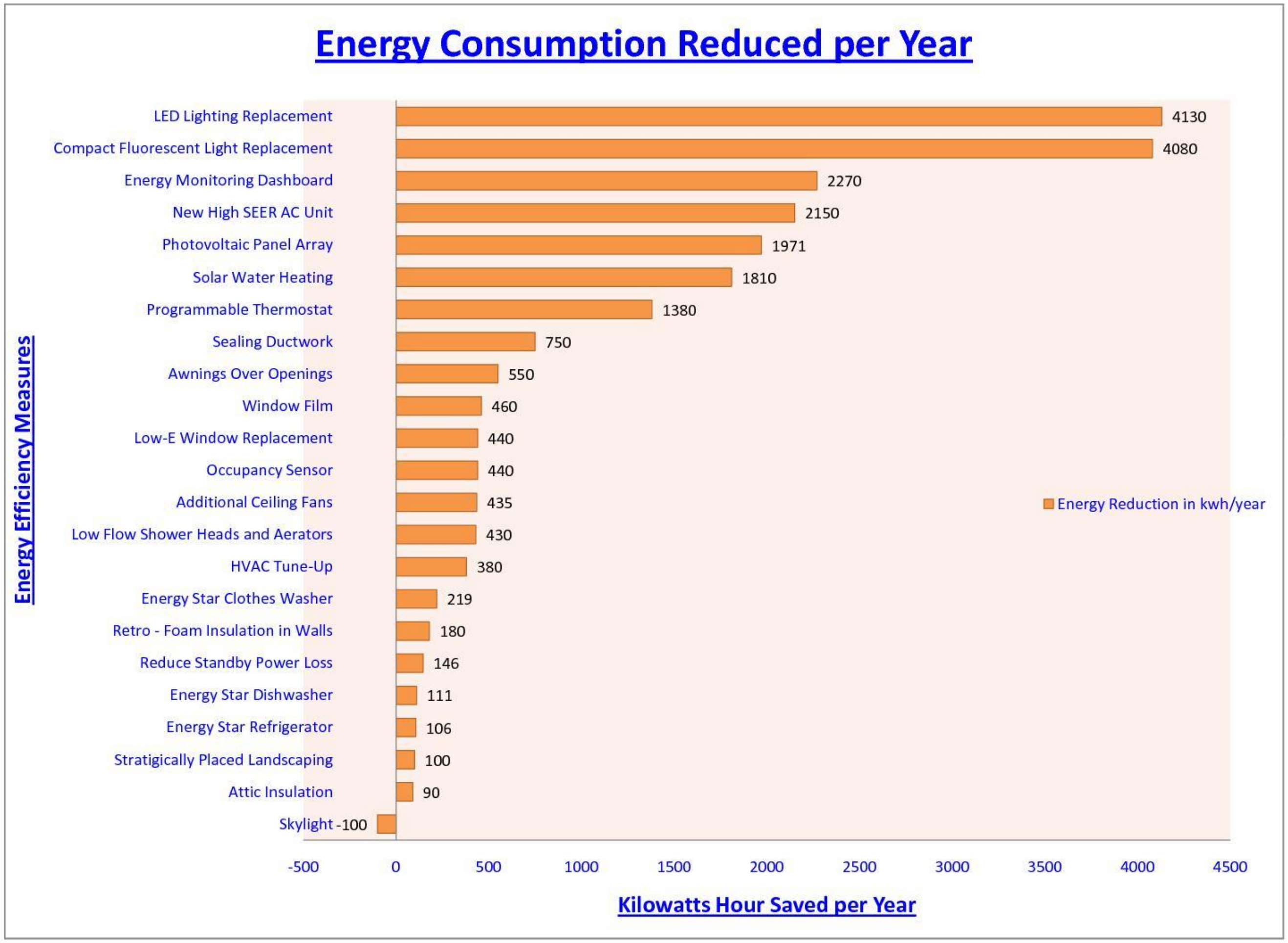


Figure 5-2. Energy Consumption Reduced per Year.

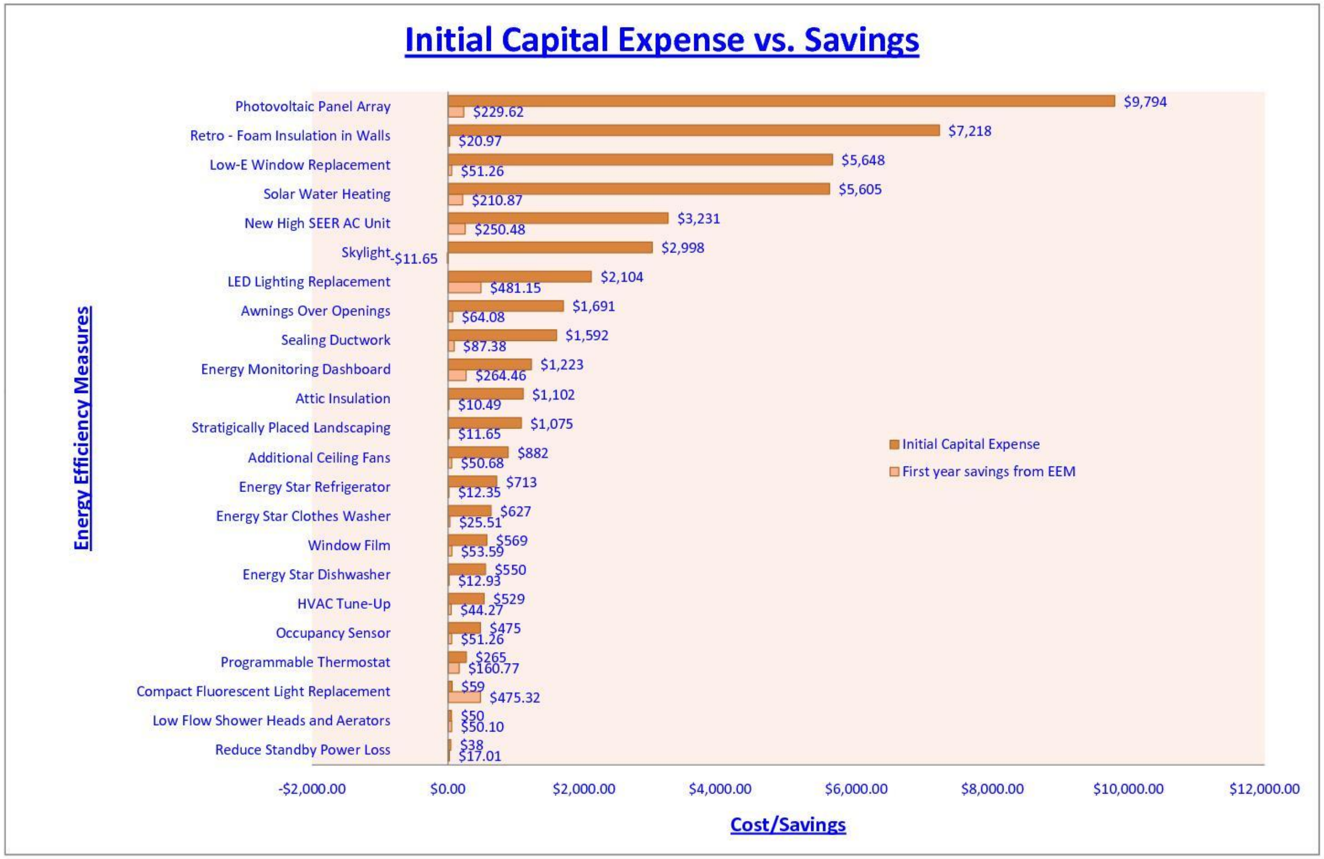


Figure 5-3. Initial Capital Expense vs. Savings.

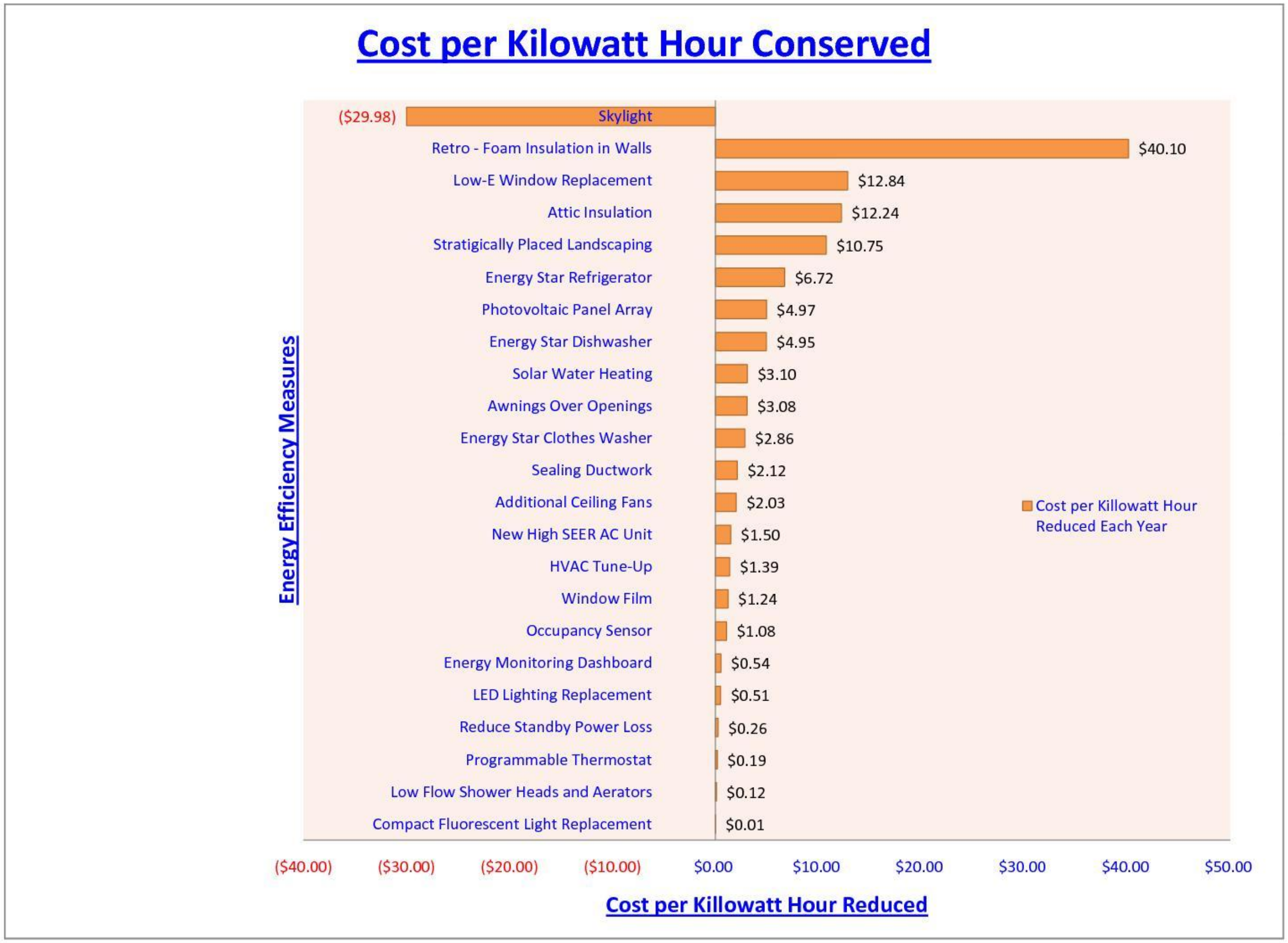


Figure 5-4. Cost per Kilowatt Hour Conserved.

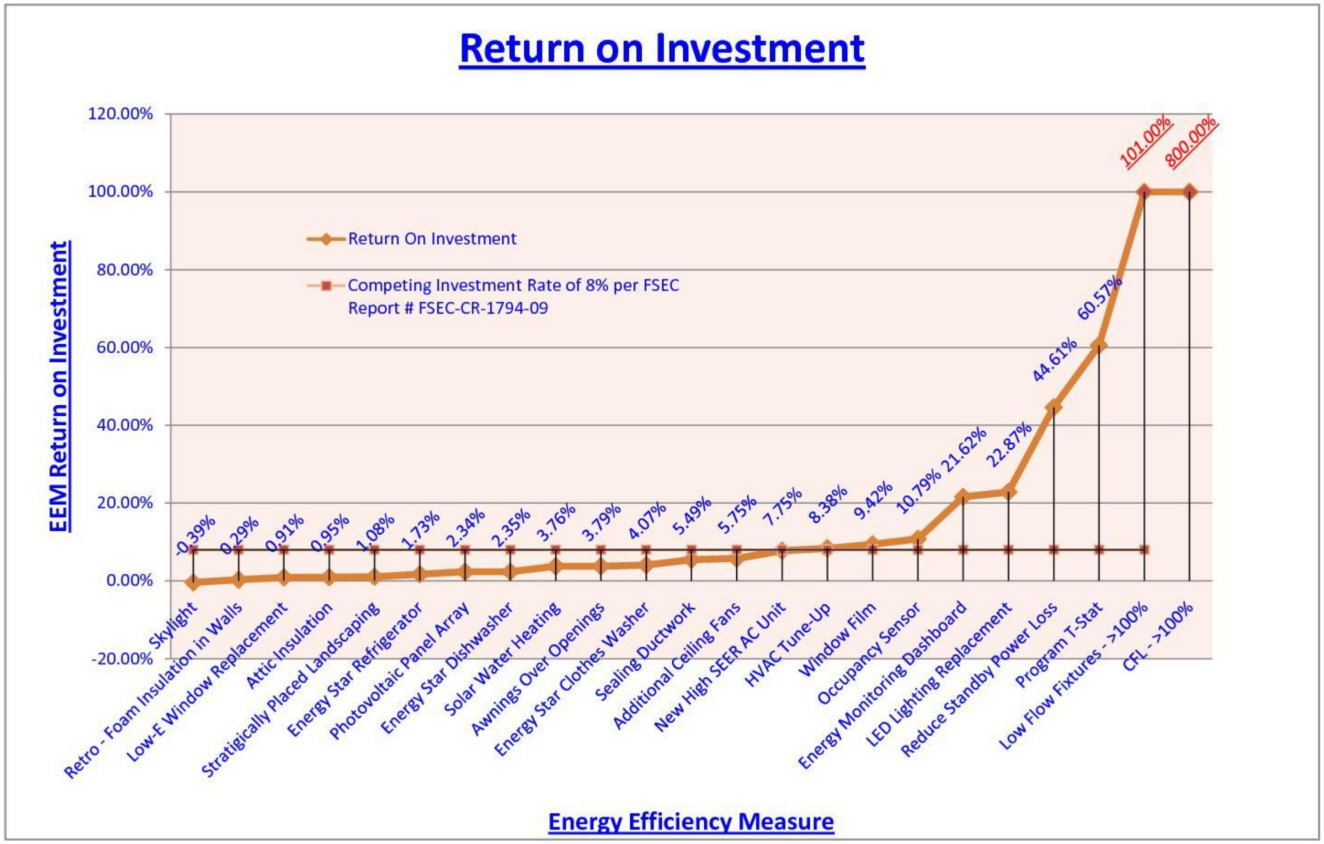


Figure 5-5. Return on Investment.

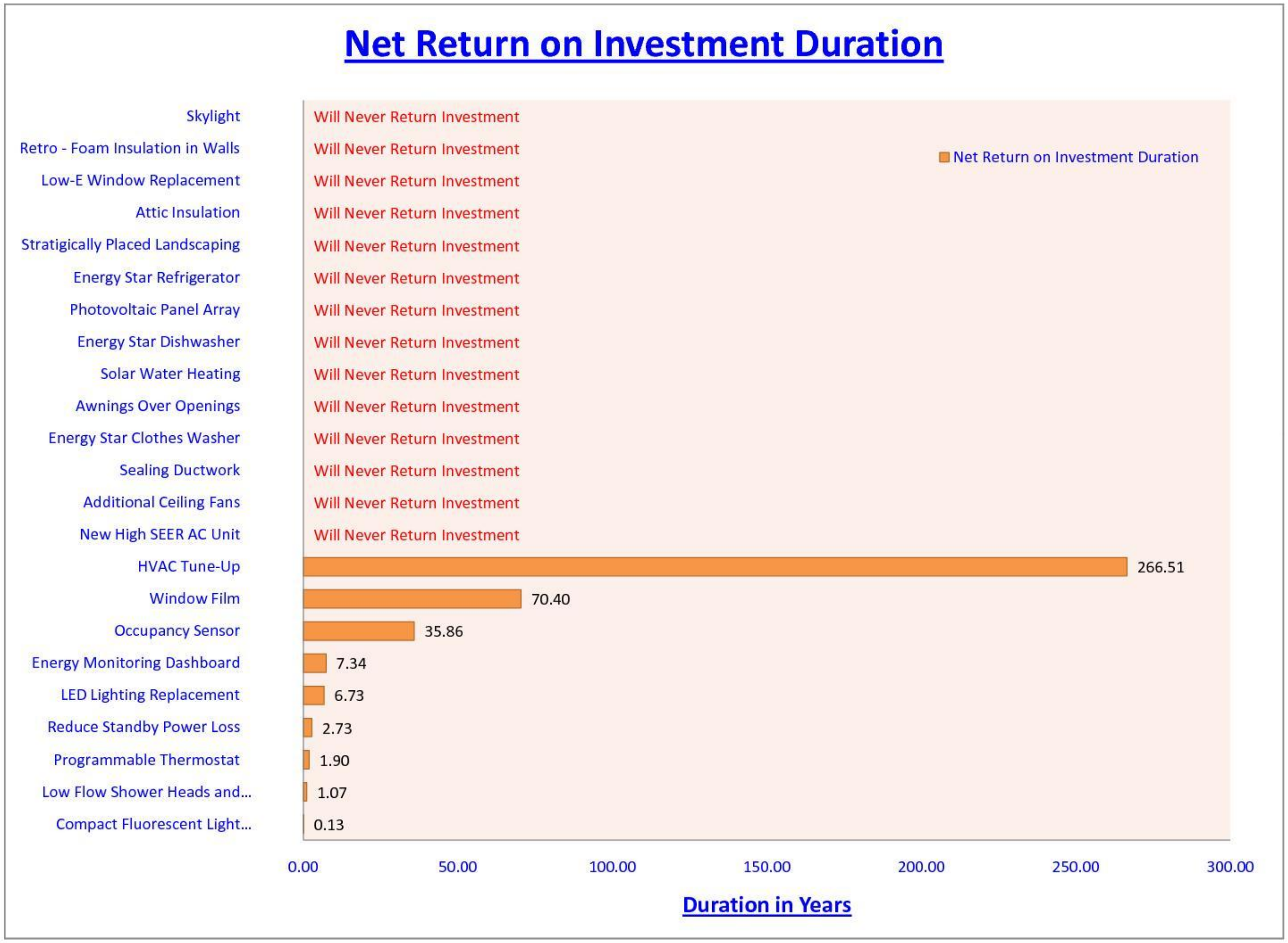
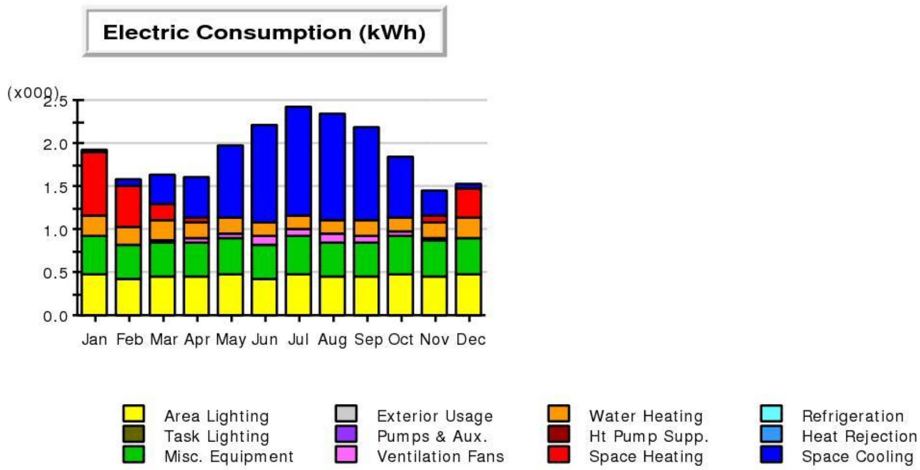


Figure 5-6. Duration of Return on Investment.

APPENDIX A
BASE LINE ENERGY MODEL THE MODEL HOUSE



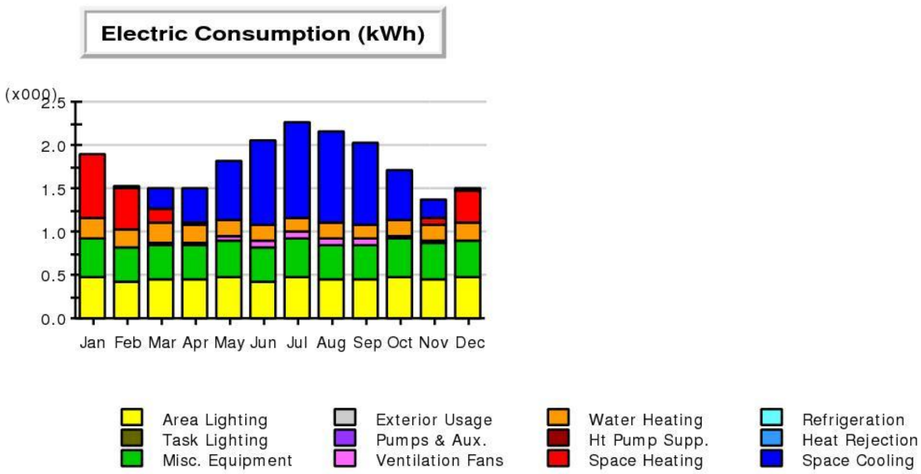
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.03	0.06	0.34	0.50	0.83	1.13	1.26	1.23	1.09	0.72	0.28	0.06	7.53
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.74	0.48	0.16	0.03	-	-	-	-	-	-	0.08	0.35	1.85
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.22	0.21	0.23	0.20	0.19	0.18	0.16	0.18	0.16	0.17	0.19	0.22	2.30
Vent. Fans	0.01	0.01	0.03	0.04	0.06	0.08	0.09	0.09	0.08	0.05	0.02	0.01	0.58
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.48	0.42	0.45	0.44	0.47	0.43	0.48	0.45	0.44	0.48	0.45	0.47	5.45
Total	1.92	1.57	1.62	1.61	1.97	2.22	2.42	2.35	2.19	1.85	1.44	1.53	22.70

Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

APPENDIX B
ENERGY MODEL OF THE CEILING FAN EEM



Electric Consumption (kWh x000)

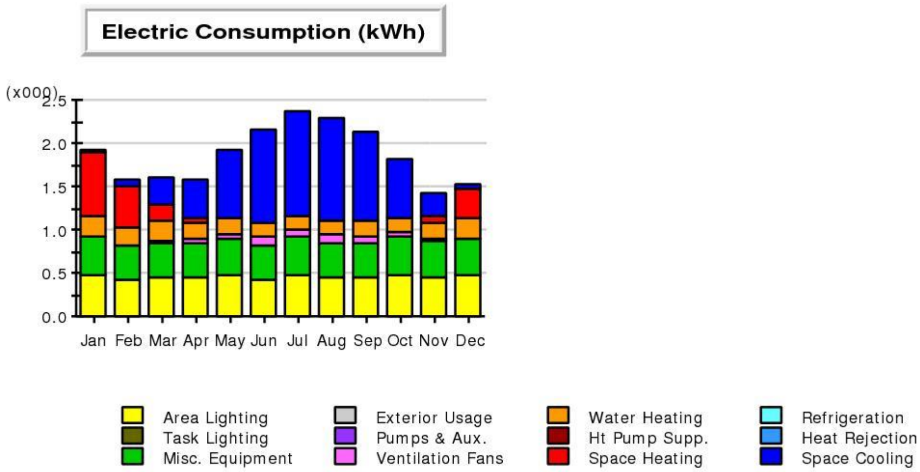
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.01	0.03	0.24	0.39	0.69	0.97	1.11	1.05	0.93	0.58	0.20	0.03	6.26
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.74	0.47	0.16	0.02	-	-	-	-	-	-	0.08	0.34	1.81
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.22	0.21	0.23	0.20	0.19	0.18	0.16	0.18	0.16	0.17	0.19	0.22	2.30
Vent. Fans	0.01	0.01	0.02	0.03	0.05	0.07	0.08	0.07	0.07	0.04	0.02	0.00	0.46
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.48	0.42	0.45	0.44	0.47	0.43	0.48	0.45	0.44	0.48	0.45	0.47	5.45
Total	1.90	1.53	1.51	1.50	1.82	2.05	2.26	2.15	2.01	1.71	1.36	1.49	21.28

Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

APPENDIX C
ENERGY MODEL OF THE HVAC TUNE-UP EEM

Project/Run: Thesis House - HVAC Tune-Up - Baseline Design Run Date/Time: 02/12/11 @ 08:15



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.03	0.06	0.32	0.47	0.79	1.08	1.20	1.17	1.04	0.68	0.27	0.05	7.15
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.74	0.48	0.16	0.03	-	-	-	-	-	-	0.08	0.35	1.85
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.22	0.21	0.23	0.20	0.19	0.18	0.16	0.18	0.16	0.17	0.19	0.22	2.30
Vent. Fans	0.01	0.01	0.03	0.04	0.06	0.08	0.09	0.09	0.08	0.05	0.02	0.01	0.58
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.48	0.42	0.45	0.44	0.47	0.43	0.48	0.45	0.44	0.48	0.45	0.47	5.45
Total	1.92	1.57	1.60	1.59	1.93	2.17	2.36	2.29	2.13	1.82	1.43	1.52	22.32

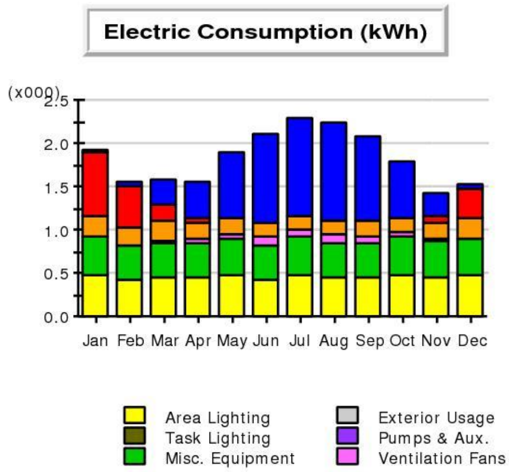
Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

eQUEST 3.64.7130 Monthly Energy Consumption by Enduse Page 1

APPENDIX D
ENERGY MODEL OF THE LEAKING HVAC DUCTWORK EEM

Project/Run: Thesis House - Leaking Ductwork - Baseline Design | Run Date/Time: 02/12/11 @ 08:24



Electric Consumption (kWh x000)

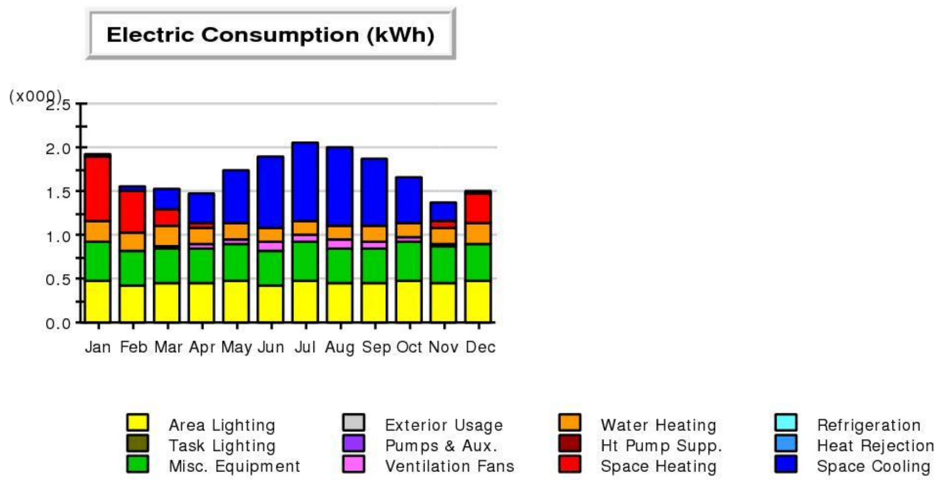
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.03	0.06	0.31	0.45	0.74	1.02	1.13	1.11	0.98	0.65	0.25	0.05	6.78
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.74	0.48	0.16	0.03	-	-	-	-	-	-	0.08	0.35	1.85
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.22	0.21	0.23	0.20	0.19	0.18	0.16	0.18	0.16	0.17	0.19	0.22	2.30
Vent. Fans	0.01	0.01	0.03	0.04	0.06	0.08	0.09	0.09	0.08	0.05	0.02	0.01	0.58
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.48	0.42	0.45	0.44	0.47	0.43	0.48	0.45	0.44	0.48	0.45	0.47	5.45
Total	1.92	1.56	1.59	1.56	1.89	2.11	2.30	2.23	2.08	1.78	1.42	1.52	21.95

Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

APPENDIX E
ENERGY MODEL OF THE HIGH SEER AC UNIT EEM

Project/Run: Thesis House - High SEER Unit - Baseline Design   Run Date/Time: 02/12/11 @ 08:33



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.02	0.05	0.24	0.35	0.59	0.81	0.90	0.88	0.78	0.51	0.20	0.04	5.38
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.74	0.48	0.16	0.03	-	-	-	-	-	-	0.08	0.35	1.85
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.22	0.21	0.23	0.20	0.19	0.18	0.16	0.18	0.16	0.17	0.19	0.22	2.30
Vent. Fans	0.01	0.01	0.03	0.04	0.06	0.08	0.09	0.09	0.08	0.05	0.02	0.01	0.58
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.48	0.42	0.45	0.44	0.47	0.43	0.48	0.45	0.44	0.48	0.45	0.47	5.45
Total	1.91	1.55	1.52	1.47	1.73	1.90	2.06	2.00	1.87	1.65	1.36	1.51	20.55

Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

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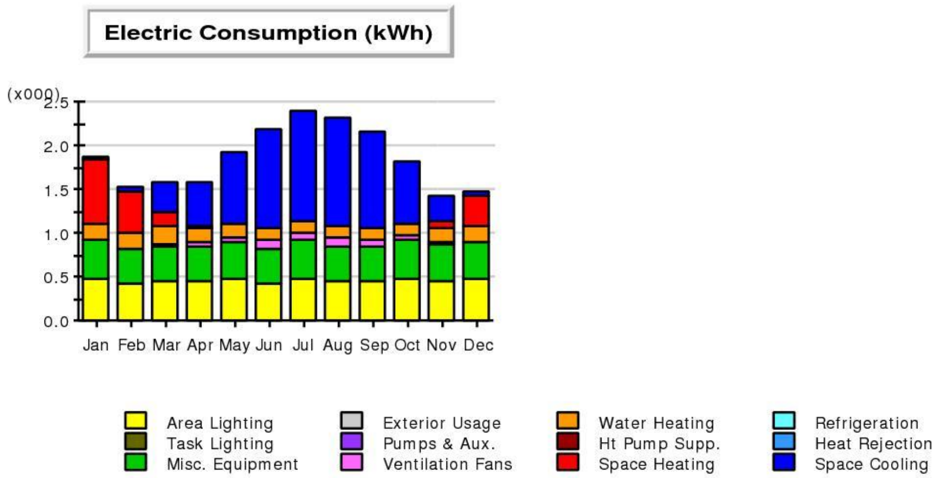
APPENDIX F
ENERGY MODEL OF THE LOW FLOW SHOWER HEADS AND AERATORS EEM

Project/Run: Thesis House - Low Flow Fixtures - Baseline Design   Run Date/Time: 02/12/11 @ 08:54



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.03	0.06	0.34	0.50	0.83	1.13	1.26	1.23	1.09	0.72	0.28	0.06	7.53
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.74	0.48	0.16	0.03	-	-	-	-	-	-	0.08	0.35	1.85
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.18	0.17	0.19	0.16	0.15	0.15	0.13	0.14	0.13	0.14	0.15	0.18	1.87
Vent. Fans	0.01	0.01	0.03	0.04	0.06	0.08	0.09	0.09	0.08	0.05	0.02	0.01	0.58
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.48	0.42	0.45	0.44	0.47	0.43	0.48	0.45	0.44	0.48	0.45	0.47	5.45
Total	1.88	1.53	1.58	1.58	1.93	2.19	2.39	2.32	2.16	1.82	1.41	1.49	22.27

Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

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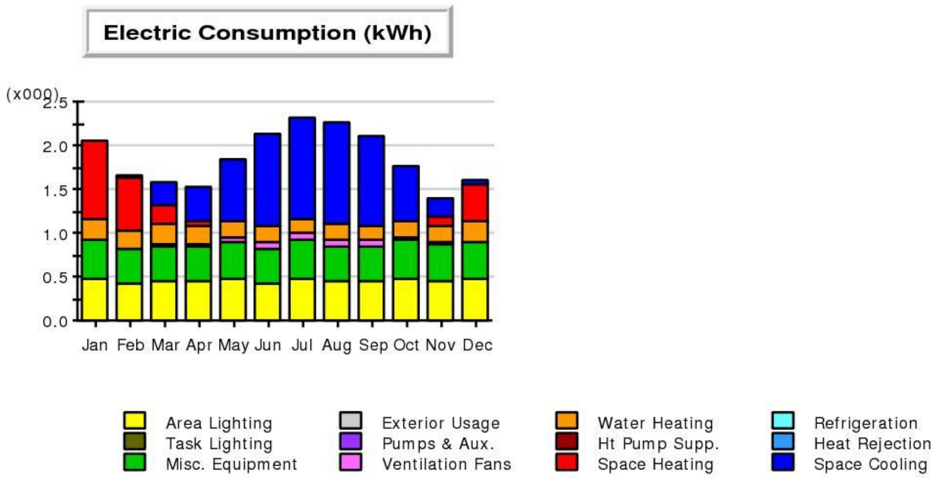
APPENDIX G
ENERGY MODEL OF THE WINDOW FILM EEM



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.01	0.03	0.26	0.40	0.72	1.04	1.16	1.15	1.01	0.64	0.22	0.03	6.68
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.89	0.60	0.22	0.04	-	-	-	-	-	-	0.11	0.44	2.30
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.22	0.21	0.23	0.20	0.19	0.18	0.16	0.18	0.16	0.17	0.19	0.22	2.30
Vent. Fans	0.01	0.01	0.02	0.03	0.05	0.08	0.08	0.08	0.07	0.05	0.02	0.01	0.51
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.48	0.42	0.45	0.44	0.47	0.43	0.48	0.45	0.44	0.48	0.45	0.47	5.45
Total	2.05	1.65	1.58	1.52	1.86	2.12	2.32	2.26	2.10	1.77	1.41	1.59	22.24

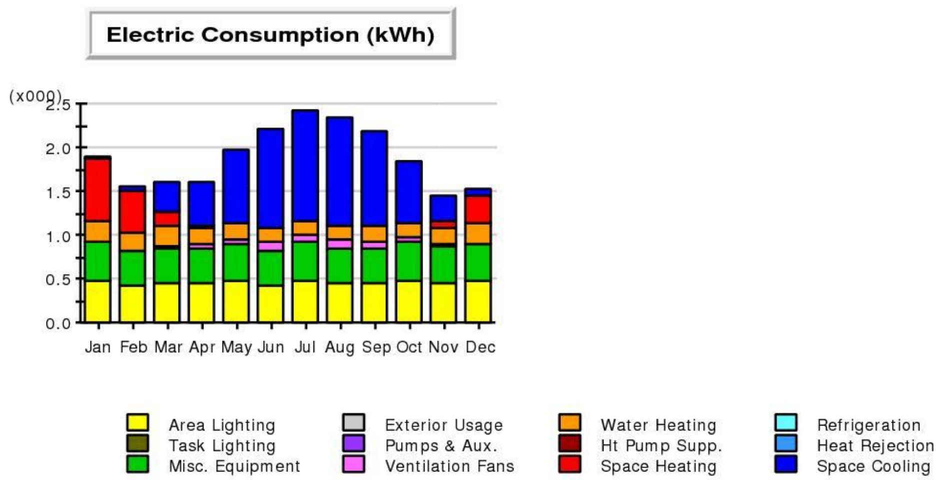
Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

APPENDIX H

ENERGY MODEL OF THE BLOWN IN ATTIC INSULATION EEM

Project/Run: Thesis House - Added Attic Insulation - Baseline Design   Run Date/Time: 02/13/11 @ 18:41



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.03	0.06	0.34	0.49	0.82	1.13	1.25	1.23	1.09	0.72	0.28	0.05	7.49
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.73	0.47	0.16	0.03	-	-	-	-	-	-	0.08	0.34	1.80
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.22	0.21	0.23	0.20	0.19	0.18	0.16	0.18	0.16	0.17	0.19	0.22	2.30
Vent. Fans	0.01	0.01	0.03	0.04	0.06	0.08	0.09	0.09	0.08	0.05	0.02	0.01	0.57
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.48	0.42	0.45	0.44	0.47	0.43	0.48	0.45	0.44	0.48	0.45	0.47	5.45
Total	1.90	1.56	1.61	1.61	1.96	2.22	2.42	2.35	2.18	1.85	1.44	1.51	22.61

Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

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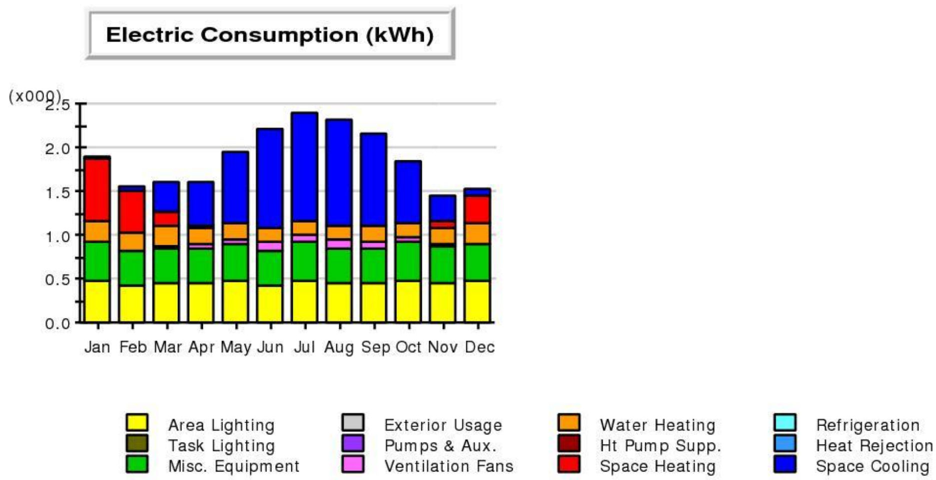
APPENDIX I
ENERGY MODEL OF THE RETRO-FOAM IN WALLS EEM



Electric Consumption (kWh x000)

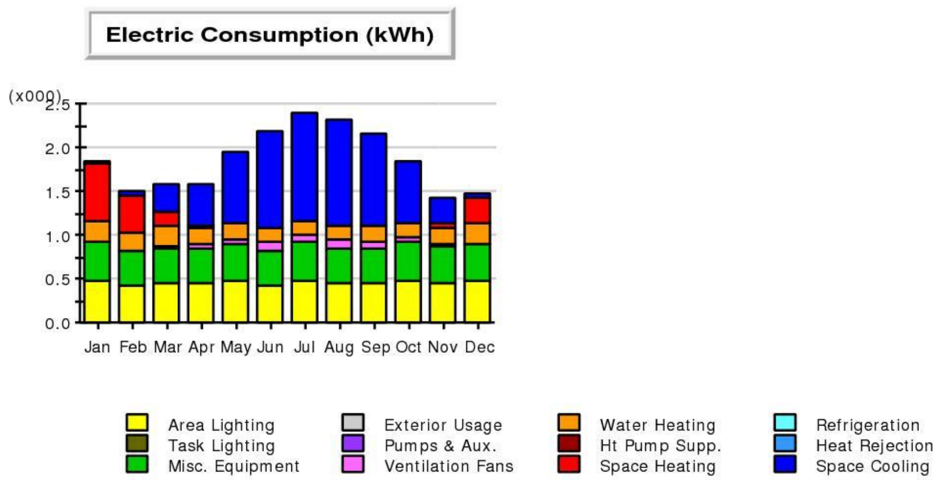
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.03	0.06	0.34	0.49	0.82	1.11	1.23	1.20	1.07	0.71	0.28	0.06	7.39
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.73	0.47	0.16	0.03	-	-	-	-	-	-	0.08	0.34	1.80
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.22	0.21	0.23	0.20	0.19	0.18	0.16	0.18	0.16	0.17	0.19	0.22	2.30
Vent. Fans	0.01	0.01	0.03	0.04	0.06	0.08	0.09	0.09	0.08	0.05	0.02	0.01	0.57
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.48	0.42	0.45	0.44	0.47	0.43	0.48	0.45	0.44	0.48	0.45	0.47	5.45
Total	1.91	1.56	1.61	1.61	1.96	2.20	2.40	2.32	2.16	1.84	1.44	1.51	22.52

Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

APPENDIX J
ENERGY MODEL OF THE LOW E GLAZING EEM

Project/Run: Thesis House - Low-E Glass - Baseline Design	Run Date/Time: 02/12/11 @ 10:42



Electric Consumption (kWh x000)

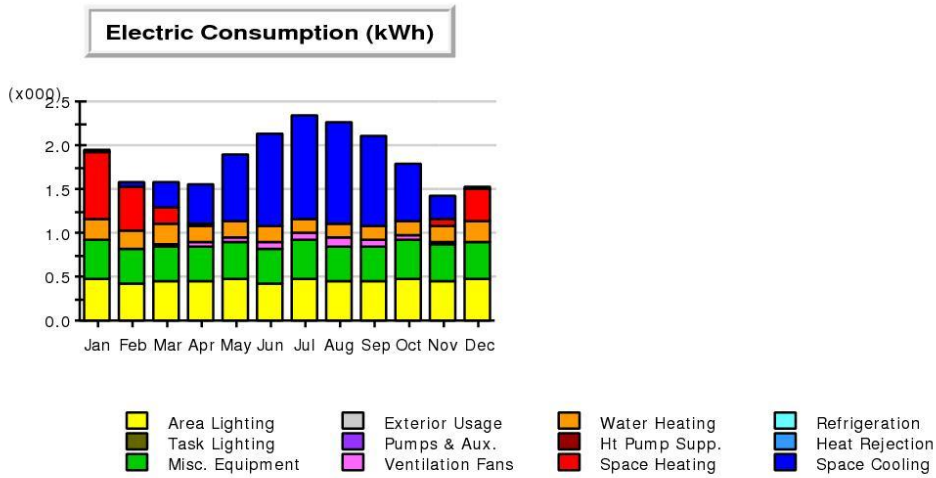
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.03	0.06	0.33	0.48	0.81	1.10	1.23	1.20	1.07	0.71	0.27	0.05	7.34
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.66	0.43	0.14	0.02	-	-	-	-	-	-	0.06	0.30	1.62
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.22	0.21	0.23	0.20	0.19	0.18	0.16	0.18	0.16	0.17	0.19	0.22	2.30
Vent. Fans	0.01	0.01	0.03	0.04	0.06	0.08	0.09	0.09	0.08	0.05	0.02	0.01	0.56
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.48	0.42	0.45	0.44	0.47	0.43	0.48	0.45	0.44	0.48	0.45	0.47	5.45
Total	1.84	1.51	1.59	1.59	1.94	2.19	2.39	2.32	2.16	1.84	1.42	1.47	22.26

Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

APPENDIX K
ENERGY MODEL OF THE WINDOW AWNING EEM

Project/Run: Thesis House - Awnings - Baseline Design Run Date/Time: 02/12/11 @ 11:38



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.02	0.05	0.29	0.43	0.75	1.05	1.18	1.16	1.02	0.66	0.25	0.04	6.90
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.78	0.51	0.18	0.03	-	-	-	-	-	-	0.09	0.38	1.96
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.22	0.21	0.23	0.20	0.19	0.18	0.16	0.18	0.16	0.17	0.19	0.22	2.30
Vent. Fans	0.01	0.01	0.02	0.03	0.06	0.08	0.09	0.09	0.08	0.05	0.02	0.01	0.53
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.48	0.42	0.45	0.44	0.47	0.43	0.48	0.45	0.44	0.48	0.45	0.47	5.45
Total	1.94	1.58	1.58	1.55	1.89	2.14	2.33	2.27	2.11	1.79	1.41	1.54	22.15

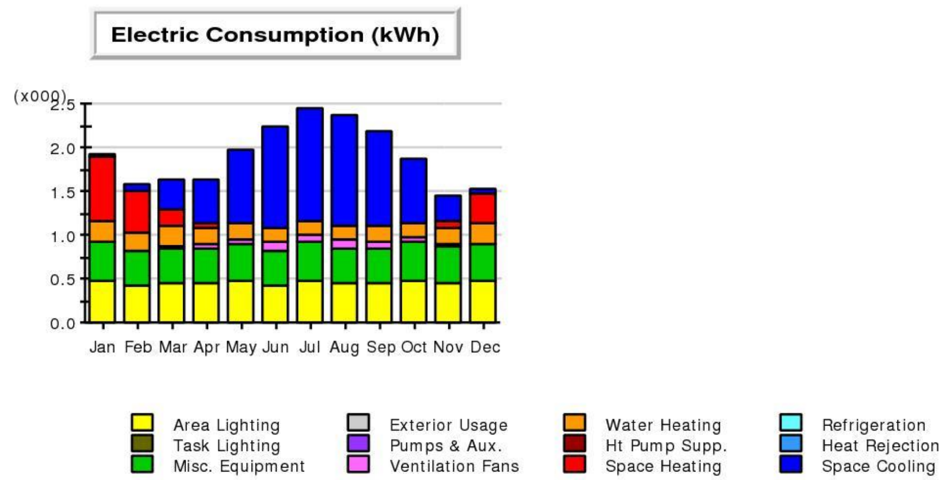
Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

eQUEST 3.64.7130 Monthly Energy Consumption by Enduse Page 1

APPENDIX L
ENERGY MODEL OF THE SKYLIGHT EEM

Project/Run: Thesis House Skylight - Baseline Design Run Date/Time: 02/14/11 @ 14:30



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.03	0.07	0.35	0.51	0.84	1.14	1.27	1.24	1.10	0.73	0.29	0.06	7.62
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.74	0.48	0.16	0.03	-	-	-	-	-	-	0.08	0.35	1.85
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.22	0.21	0.23	0.20	0.19	0.18	0.16	0.18	0.16	0.17	0.19	0.22	2.30
Vent. Fans	0.01	0.01	0.03	0.04	0.06	0.08	0.09	0.09	0.08	0.05	0.02	0.01	0.58
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.48	0.42	0.45	0.44	0.47	0.43	0.48	0.45	0.44	0.48	0.45	0.47	5.45
Total	1.92	1.57	1.63	1.63	1.98	2.24	2.44	2.36	2.20	1.86	1.45	1.53	22.80

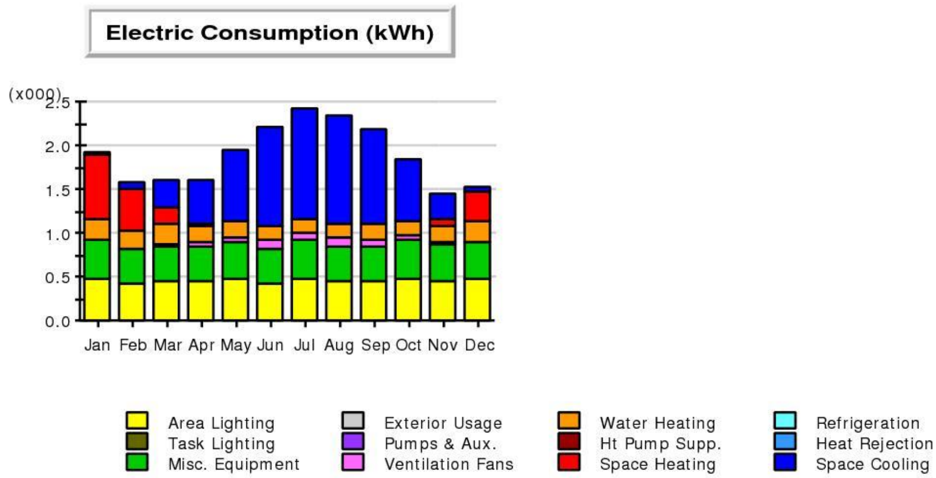
Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

eQUEST 3.64.7130 Monthly Energy Consumption by Enduse Page 1

APPENDIX M
ENERGY MODEL OF THE STRATEGICALLY PLACED LANDSCAPE EEM

Project/Run: Thesis House - Strategically Placed Landscape - Baseline Design | Run Date/Time: 02/14/11 @ 15:59



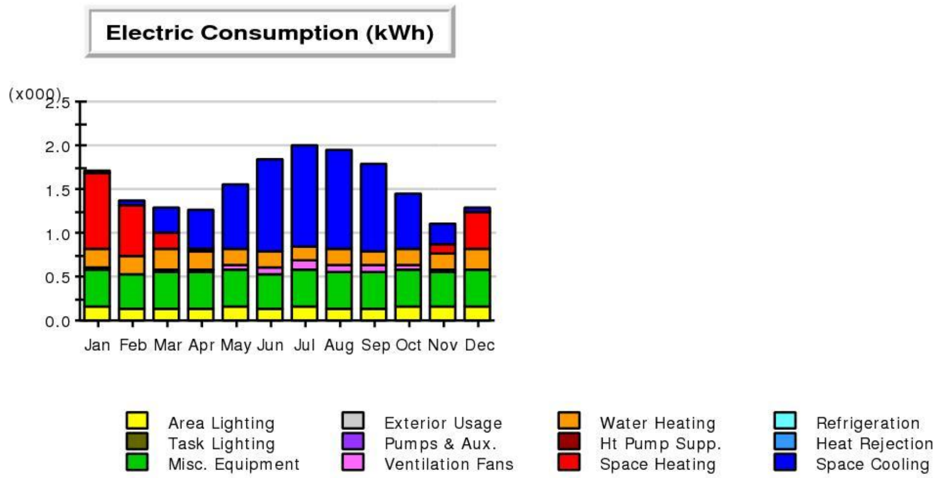
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.03	0.06	0.34	0.49	0.81	1.12	1.25	1.22	1.08	0.71	0.28	0.05	7.44
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.74	0.48	0.17	0.03	-	-	-	-	-	-	0.08	0.35	1.84
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.22	0.21	0.23	0.20	0.19	0.18	0.16	0.18	0.16	0.17	0.19	0.22	2.30
Vent. Fans	0.01	0.01	0.03	0.04	0.06	0.08	0.09	0.09	0.08	0.05	0.02	0.01	0.57
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.48	0.42	0.45	0.44	0.47	0.43	0.48	0.45	0.44	0.48	0.45	0.47	5.45
Total	1.92	1.57	1.61	1.60	1.95	2.21	2.41	2.34	2.18	1.85	1.44	1.52	22.60

Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

APPENDIX N
ENERGY MODEL OF THE CFL EEM



Electric Consumption (kWh x000)

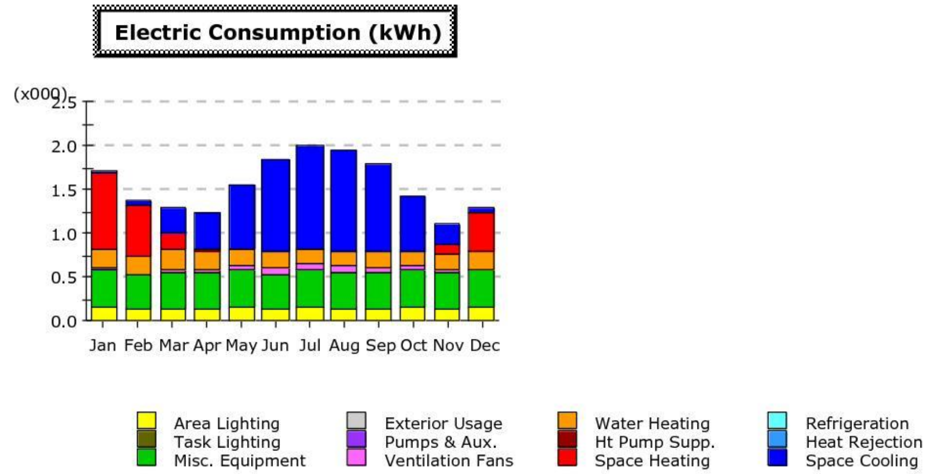
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.02	0.05	0.29	0.44	0.75	1.05	1.18	1.15	1.01	0.63	0.23	0.04	6.84
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.86	0.57	0.20	0.04	-	-	-	-	-	-	0.11	0.44	2.22
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.22	0.21	0.23	0.20	0.19	0.18	0.16	0.18	0.16	0.17	0.19	0.22	2.30
Vent. Fans	0.01	0.01	0.02	0.03	0.06	0.08	0.08	0.08	0.07	0.05	0.02	0.01	0.51
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.15	0.14	0.14	0.14	0.15	0.14	0.15	0.14	0.14	0.15	0.15	0.15	1.76
Total	1.70	1.36	1.30	1.25	1.56	1.84	2.01	1.96	1.80	1.44	1.11	1.28	18.62

Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

APPENDIX O
ENERGY MODEL OF THE LED LIGHTING EEM

Project/Run: Thesis House - LED Lighting REVISED 1 - Baseline Design   Run Date/Time: 03/02/11 @ 18:44



Electric Consumption (kWh x000)

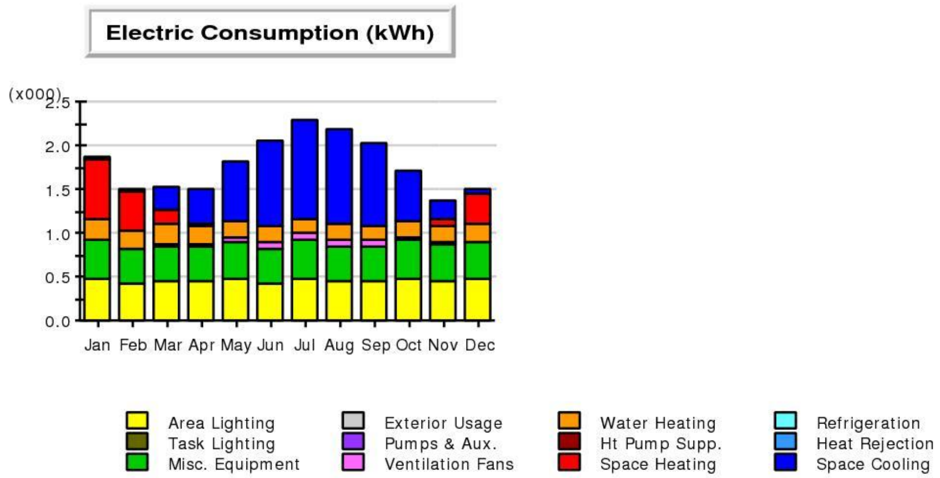
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.02	0.05	0.29	0.43	0.74	1.05	1.18	1.15	1.01	0.63	0.23	0.04	6.83
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.86	0.57	0.20	0.04	-	-	-	-	-	-	0.11	0.45	2.22
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.22	0.21	0.23	0.20	0.19	0.18	0.16	0.18	0.16	0.17	0.19	0.22	2.30
Vent. Fans	0.01	0.01	0.02	0.03	0.05	0.08	0.08	0.08	0.07	0.05	0.02	0.01	0.51
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.15	0.13	0.14	0.14	0.15	0.14	0.15	0.14	0.14	0.15	0.14	0.15	1.70
Total	1.70	1.36	1.29	1.25	1.56	1.84	2.00	1.95	1.79	1.43	1.11	1.28	18.57

Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

APPENDIX P

ENERGY MODEL OF THE PROGRAMMABLE THERMOSTATS EEM



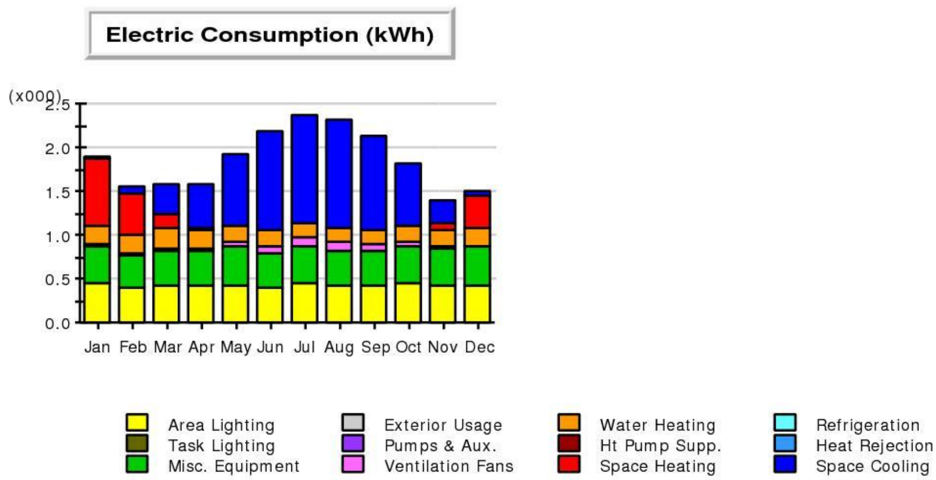
Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.01	0.04	0.25	0.39	0.69	0.98	1.13	1.07	0.95	0.60	0.20	0.03	6.34
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.70	0.45	0.16	0.03	-	-	-	-	-	-	0.08	0.34	1.75
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.22	0.21	0.23	0.20	0.19	0.18	0.16	0.18	0.16	0.17	0.19	0.22	2.30
Vent. Fans	0.01	0.01	0.02	0.03	0.05	0.07	0.08	0.08	0.07	0.04	0.02	0.00	0.48
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.48	0.42	0.45	0.44	0.47	0.43	0.48	0.45	0.44	0.48	0.45	0.47	5.45
Total	1.86	1.51	1.52	1.50	1.82	2.06	2.28	2.17	2.03	1.72	1.36	1.49	21.32

Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

APPENDIX Q
ENERGY MODEL OF THE OCCUPANCY SENSOR EEM



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.03	0.06	0.34	0.49	0.82	1.12	1.25	1.22	1.08	0.71	0.27	0.05	7.44
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.76	0.49	0.17	0.03	-	-	-	-	-	-	0.08	0.36	1.89
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.22	0.21	0.23	0.20	0.19	0.18	0.16	0.18	0.16	0.17	0.19	0.22	2.30
Vent. Fans	0.01	0.01	0.03	0.04	0.06	0.08	0.09	0.09	0.08	0.05	0.02	0.01	0.57
Pumps & Aux.	0.01	0.01	0.00	0.00	-	-	-	-	-	-	0.00	0.01	0.03
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.43	0.38	0.41	0.40	0.42	0.39	0.43	0.41	0.40	0.43	0.41	0.42	4.96
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.44	0.39	0.41	0.41	0.43	0.40	0.44	0.41	0.41	0.44	0.42	0.43	5.06
Total	1.90	1.55	1.58	1.58	1.92	2.18	2.38	2.31	2.14	1.81	1.41	1.50	22.26

Gas Consumption (Btu)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool													
Heat Reject.													
Refrigeration													
Space Heat													
HP Supp.													
Hot Water													
Vent. Fans													
Pumps & Aux.													
Ext. Usage													
Misc. Equip.													
Task Lights													
Area Lights													
Total													

APPENDIX R
PROTOCOL FOR MODEL HOUSE

General Parameters

- 3 bedroom, 2 baths and 2 car garage.
- 1,803 sqft under air. 21,165 sqft total.
- Built in 1988.
- Energy efficiency based on 1987 Florida Energy Code.
- Perimeter of 248 lnft.
- Exterior wall height is 8'-0".
- Exterior wall surface area 1,984 sqft.
- Energy source is electric without access to gas.
- North central Florida climate zone.

Site

- Model is located on ¼ acre site.
- No trees or adjacent structures shading site.
- House is orientated East/West with the front facing direction West.

Schedule and Occupancy

- 3 residents in home.
- Weekday peak loads are 6-9am and 5-10pm Monday – Friday. Weekend peak loads are 7am – 10pm Saturday, Sunday and holidays.
- US standard holidays observed.

Interior Loads

- Average lighting intensity of .9 Watts per sqft
- Plug in devise intensity of .75 Watts per sqft
- Utility cost of $.1165 per kilowatt.

Shell Construction

- Exterior wall composed of stucco, 8" block wall, ¾" wood furring strips and 5/8" gypsum board. Block reinforced with rebar in grout filled cells every 24" on center.
- Roof composed of dark colored asphalt shingles over felt paper and 5/8" OSB.
- Wood trusses every 24" on center.
- 18" soffit overhang.
- Roof on a 5/12 pitch
- R19 insulation located at attic floor level.
- 4" monolithically poured concrete slab.
- Exterior glazing is 15% of floor space.
- Windows are operable single hung with 1/8" glass.
- Exterior doors are insulated metal doors.

HVAC System

- Split system. Condenser unit located outside. Air handler unit located in conditioned AC closet.
- Direct return.
- 10 SEER efficiency.
- Cooling set point of 76 degrees. Heating Set point of 65 degrees.
- Average heat gain per person is 450 BTU/hour (250 BTU/h sensible and 200 BTU/hour latent).

Hot Water System

- 40 gallon storage type style system.
- 4,500 Watt output.
- Average water use of 25.8 gallons per person per day.
- Input temp of 75 degrees.
- Output temp of 120 degrees.
- Electric fuel source.

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BIOGRAPHICAL SKETCH

Joe Burgett was born in 1980 in Saint Petersburg Florida. He is the younger of 2 sons to Dan and Sally Burgett. He graduated from Northeast High School in the spring of 1998. After graduating high school Joe attended the University of Florida where he received his Bachelor of Science from the M.E. Rinker, Sr. School of Building Construction. After graduating, Joe spent eight years in the construction industry working largely for The Weitz Company. While in the industry, Joe worked primarily on state and local government project but has experience with hotels, hospitals, biomedical research, schools, multifamily-condos, single family residences and retirement campuses. The majority of his construction experience was in operations serving as a superintendent and project manager however he also spent several years in preconstruction. While in preconstruction he estimated over 800 million dollars of work. In 2010, Joe returned to the University of Florida to pursue master's and PhD degrees in construction management. He is currently enrolled in the M.E. Rinker, Sr. School of Building Construction and is expected to graduate in the spring of 2011.

Joe is married to his wife, Jill and has two daughters with her. His youngest daughter, Emma, was born in March of 2010 and his older daughter, Kate, was born in September of 2008. Joe and his family currently reside in Gainesville, Florida.