A CASE STUDY IN WHOLE BUILDING ENERGY MODELING WITH PRACTICAL APPLICATIONS FOR RESIDENTIAL CONSTRUCTION

by

CODY WILLIAM KNUTH

A REPORT

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Approved by:

Major Professor
Charles L. Burton

Abstract

An energy analysis was performed on a Midwestern residence to evaluate its performance based on energy use. A model of the actual house was replicated using eQuest and adjusted until its projected utility bills matched the actual yearly bills. This model was used to gauge how potential improvements made to the envelope and HVAC systems lowered the energy use. The results were documented after each improvement the feasible options were considered. The top alternatives were then combined to see how much money could be saved through renovating an existing home or through constructing a new residence. The overall goal of this report was to use the resulting improvement data as a reference for homeowners or homebuilders who are interested in conserving energy and money through residential improvements.

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Chapter 1 - Introduction

Prospective home owners today do not have resources or concrete facts about the best way to save money when building a home or improving the one they have. The purpose of this report is to look at energy efficiency with respect to residential applications and what home owners, builders, or renovators care about most: money. Saving money is something that almost every energy-conscious home owner is concerned with. There are many ways to reduce energy use in homes, but this analysis will focus on improving the building envelope or heating, ventilation, and air-conditioning (HVAC) systems of a residence located in the Midwestern United States.

Figure 1-1 Photograph of the Residence Being Analyzed

The residence analyzed for this research is located in Manhattan, Kansas and was chosen because of its accessibility and resources. The owner of the residence is a professor at Kansas State University and has worked in the construction and architectural engineering industry for 50 years. He is very familiar with the construction of his home, because he built it, but he also has extensive knowledge of the construction industry in general and the costs associated with building a house or installing the systems. He has also kept HVAC data and utility bills dating back several years. The fan operating hours for his furnace with direct expansion cooling have been recorded dating back 20 years. Electric and natural gas utility bills are available for the past several years as well, though only the recent bills were used to obtain an average accurate average energy use based on recent weather trends.

The residence is located in Climate Zone 4A and all energy bill savings that resulted from improvements made to the envelope or systems are typical of other houses in the region ("ASHRAE 90.2", 2007). If improvements explored in this analysis are made to a residence or model located in a different climate zone, then the savings will be different. This is because the weather will be different in areas that are farther north or south of zone 4 due to the change of the sun's path. A northern climate would expect much more heating during the winter, so the gas use would change while a southern climate would demand more cooling. Other than the local climate, the current construction of the residence and the efficiency of its HVAC system will affect the annual energy use the most, as well as adjusting the interior thermostatic setpoints. The construction and system will be discussed later in detail, but the other details of the house will be introduced in the following paragraphs.

The residence analyzed has one story above-grade and one story below-grade. The above-grade frame wall is made out of 2" x 4" studs with R-15 cavity insulation and the below-grade wall is made of 8 inch concrete block. The below-grade walls have a sheet-rock finish but no insulation. The east-facing above-grade walls are the only walls to have a limestone finish. The roof has 11 inches of loose-fill fiberglass insulation installed above a sheet-rock ceiling. Full details about the building envelope will be defined in Chapter 2. The floor plan of the residence can be seen in Figure 1-2 and 1-3.

Figure 1-2 First Floor Plan

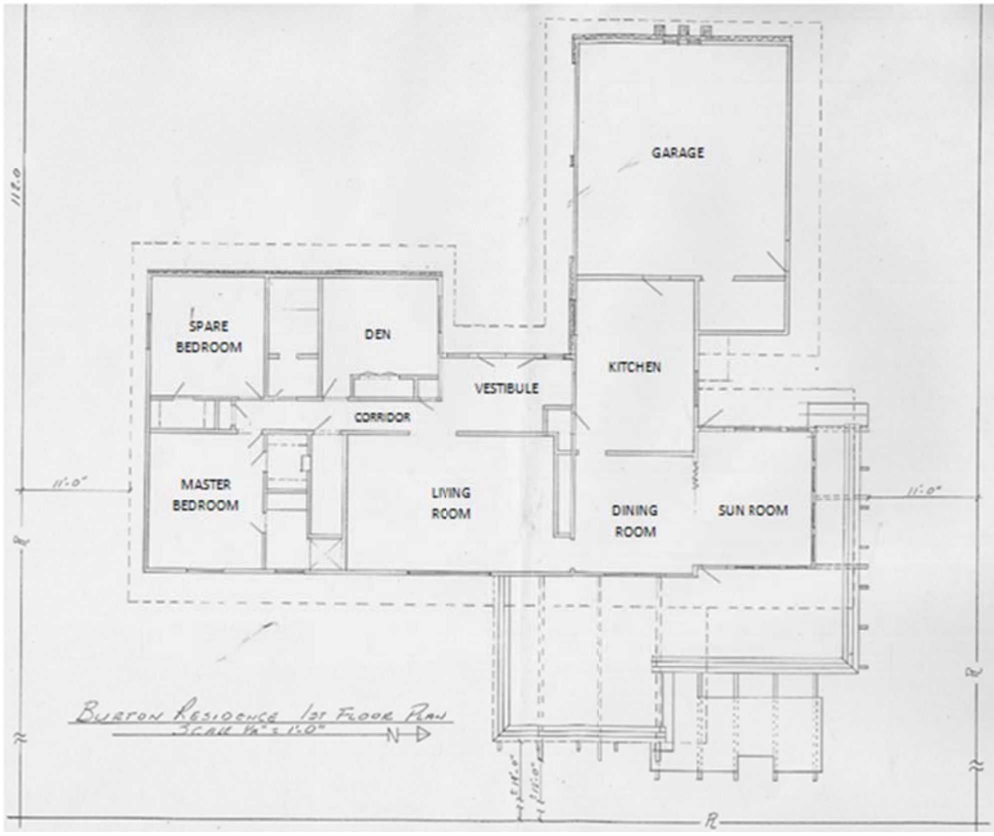
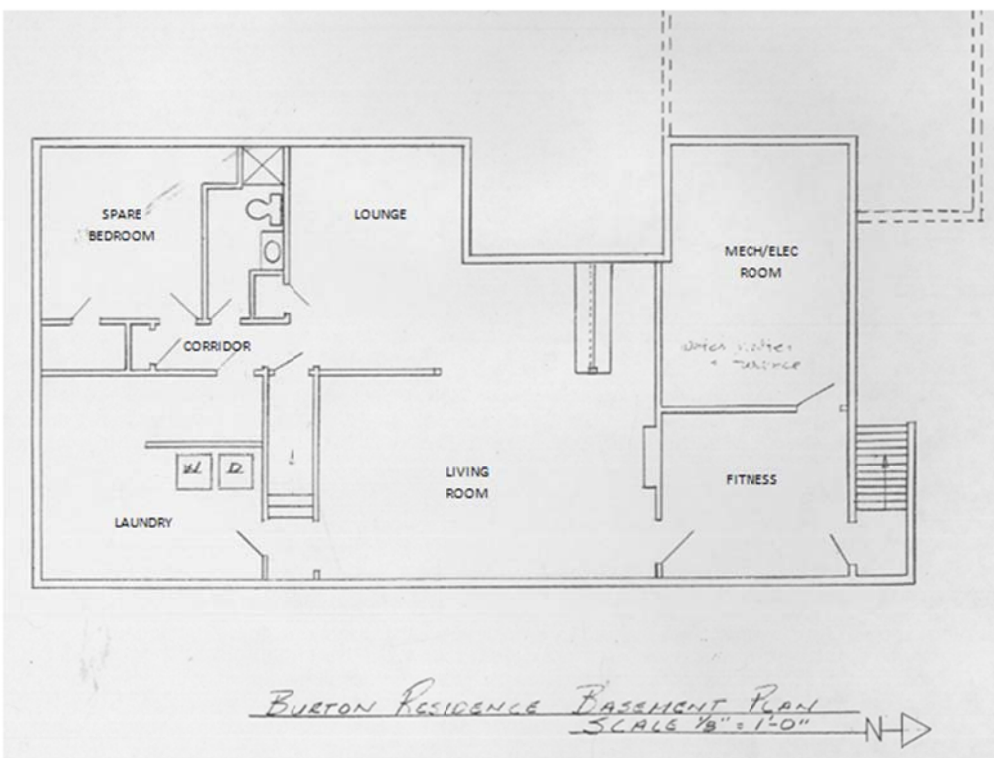


Figure 1-3 Basement Floor Plan



There are two occupants that currently live in the home where there once were 4. The main rooms used are the master bedroom, master bathroom, kitchen, sunroom, and basement living room. One of the occupants works during the day while the other is retired, though she tries to get out of the house during the day. So, the house was considered 24-hour operation, low use when building the model. Most of the other pertinent and imperative details are discussed throughout the report and covered where necessary..

The first step to building an accurate model started with running the heat transmission calculations for the building as a whole. This was done to build a foundation for the model and treat as a reference point from which to build on. The load was calculated for each room so that all information was documented and the energy model could be constructed quickly with the available references. All equipment, glass, and construction data for each room was considered and the heat gain and heat loss was analyzed. Understanding this process made the construction of the energy model more efficient. After the loads were run and the cooling and heating loads were determined, the eQuest model was then started. Once an accurate replica of the residence was modeled, improvements could then be made to the building with all energy savings analyzed.

Enhancements made to the base model were narrowed to the envelope and HVAC system efficiency because these areas generally affect energy usage the most. Upgrading the insulation of the above-grade walls, below-grade walls, and above-ceiling space was looked at extensively. Installing windows with lower center-of-glass U-values was considered. Altering the interior thermostatic setpoint during the heating and cooling seasons was experimented with. Improving the efficiency of the furnace or direct expansion cooling coils was also evaluated and the energy savings were documented. Scenarios were looked at that not only involved upgrades for the base residence or for new residences built to code, but also for older residences that may not have been built as tight as the house being analyzed. Improvements were made to a model with inefficient systems or loose construction with little insulation to show how important these areas are when it comes to the annual utility bills.

The focus of this report was finding out what could save energy and money for homeowners. Decreasing the annual utility bill projection in the model means more money for the homeowner. This was done by lowering the heat loss or heat gain in the building and conserving energy. Each improvement that has been previously discussed was experimented with and analyzed to see how much money could be saved while providing a decent payback (within 10 years). The payback period and return-on-investment equations were used so that homeowners and builders could see if paying more to upgrade would be worth it in the long-run.

Installing more insulation, more thermally resistant glass, or more efficient HVAC systems were situations that were first looked at individually. These analyses provided deliverables that included the improvement cost, cost differential compared to the base installation, annual savings, payback period and return-on-investments. A payback period was considered ideal if it was under 7 years, but the maximum was set around 10 years; any upgrade that took longer than this was considered to not be worth the cost of initial installation.

After the individual improvements were made in the model, then enhancement combinations were considered. Though an upgrade may not save significant amounts of money and not offer a fast payback by itself, maybe it would be optimal if combined with other advancements? This was a question that was focused on as well because homeowners need to be aware and educated on the type of improvements that could or should be made to their homes if they are sincerely interested in saving money.

The goal of the report: provide tangible data to homeowners and homebuilders, who have a vested interest in the current and future construction of their residence, that are interested in improving their energy savings through various upgrades that are readily available today. The data calculated will provide a reference for homeowners to utilize when thinking about long-term utility bills and what adjustments could be done now to save in the future. All data and reference material used for this report can be found in the appendices.

Chapter 2 - Preliminary Procedure

There are various problem solving techniques that are applied to different scenarios. But, in almost every case, the first step in each process is to gather the facts. Learning as much as possible about a project or situation is the best way to prepare for the road ahead. In this case, the road ahead contained extensive energy analysis of a Manhattan, Kansas residence and required a large amount of preparation. To gather facts, inspection of the building and overall familiarization with it were the first steps. Next, floor plans had to be procured from the home owner and the construction of the home had to be discussed with him as well. Then, the heat transfer loads for the building envelope had to be calculated; room and block loads. Internal heat gains were also considered such as from people and equipment.

Familiarization and Inspection

Once the direction of the analysis was decided upon, thorough investigation of the building had to take place. Becoming intimate with the project became of paramount importance. So, the very next step was to visit the residence and document all details.

The first visit took place in the fall of 2011. The first step was to walk around and take pictures of the house for future reference. This trip was about soaking up the details of the structure while looking at it from an objective standpoint. The house had to be looked at from a heat transfer perspective, not an aesthetic one. Where the wall construction type changed had to be identified as well as where the windows were and what the orientation of the building was. Were the wall exteriors wood paneling or siding, or were they made of stone? Which face contained the most windows: east, west, or south? Did the roof have an overhang that thoroughly shaded the windows at certain times of day? Did the house have a garage? The home owner also had to be questioned about the type of HVAC system installed in the house.

After answering these questions, measurements had to be taken that would not be found on the floor plans: wall heights, ceiling heights, window and door dimensions, height of the exposed basement wall above grade, and the pitch of the roof. These were all preliminary measurements. Several more trips were made to the house to check, re-check, and find new measurements after everything was said and done.

The homeowner had to be interviewed about the details of the house that could not be obtained from just a glance. The HVAC system installed in the house was a furnace with direct expansion (DX) cooling. Other important details were discussed as well such as what the thermostatic setpoints were and how flexible they were, or how often they changed. Additional information that was obtained from the owner will be discussed as relevant.

Another purpose of this trip was to obtain information about the systems from the equipment name plates. From these, the capacity of the furnace was determined to be 75,000 BTU/hr and that it has an efficiency of 94%. The motor is 12 amps and 120 volt. The air-cooled condenser and fan are 7.2 amps and 220 volt/1-phase. While in the "mechanical room", the size and capacity of the water heater was also recovered from its nameplate. The water heater has a 40 gallon storage tank and has a rated input capacity of 40,000 BTUh and an energy factor of 0.55. This data was enough to get started on the loads and prepare to create the model.

Load Calculations

Once enough data was known and all information was organized, the process of calculating the room loads for the residence began. The load calculation process used was the CLTD Method. The room loads were calculated to initiate the energy analysis process, but they were also created for reference more than anything. With the room loads, the energy model could be dissected further and data could be compared. Calculating the loads on a room-by-room basis was a way to become familiar with the residence and understand what to expect in terms of heat transfer and energy use. Any discrepancies or outliers in the model could be easily identified by looking at the heat loss or heat gain expected from the load calculations, in theory. The room loads are also a precursor to the block load that would be used to size the unit, or check the size in this case. Knowing the size of the unit is a huge part of the HVAC system included in the model. This building was modeled as a single zone because there is only one thermostat. To aid and organize the calculation process, an Excel spreadsheet was used. The complete workbook of spreadsheets used to determine the heating and cooling load can be found in the appendices. The following graphic is a copy of a spreadsheet from the workbook used to calculate the heating and cooling load for the laundry room and is inserted for reference:

Table 2-1 Load Calculation Spreadsheet for a Typical Room

Project:		Burton Estate					Page:	26	of	26	Date:	
Room:		010 Laundry					Name:	Cody Knuth				
Cooling:		*Outside db*	97.6	*wb*		75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating:		*Outside db*	2.5	*Inside db*		74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS	TRANSMISSION	ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
		Wall	S	58		0.3063	17.77	71.5	10	17	302	1270
			S	58	7.5			71.5				435
			E	58.92		0.3063	18.05	71.5	10	23	415	1290
			E	58.92	7.5			71.5				442
								71.5				
		Glass		3.75		0.81	3.04	71.5	10	22.6	69	217
								71.5		22.6		
		Partitions						71.5		22.6		
								71.5		22.6		
		Doors						71.5				
								71.5				
								71.5				
	7S,7T	ROOF/CEILING						71.5				
	7V,17	FLOOR		227	1.7			71.5				386
								TRANSMISSION SUBTOTALS			786	4041
	SOLAR	ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
		GLASS	windows			N						
			doors									
		GLASS	windows			S						
			doors									
		GLASS	windows	3.75		E	0.35	164			215	
			doors									
		GLASS	windows			W						
			doors									
									SOLAR SUBTOTAL		215	
INTERNAL LOADS	ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts							CLG SENS LOAD	
		227	0.705	160			Incand.	Watts x 3.413 = BTUh			546	
							Fluor.	Watts x 4.1 = BTUh				
								Watts x 3.413 = BTUh				
									ELECT SUBTOTAL		546	
	PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea						CLG LAT LOAD	CLG SENS LOAD	
	EQUIP	EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12				
		1		4000							4000	
							EQUIPMENT SUBTOTALS				4000	
INFILT		Tbl 13A & 13B ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Space CLG		Q_L = CFM x .69 x ΔG			71.5	22.6	40			
		Space HTG		Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
		Door CLG					71.5	22.6	40			
		Door HTG					71.5	22.6	40			
							INFILTRATION SUBTOTALS					
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration											5547	4041
											CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)											257	107
VENT		Tbl 14 ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
				Q_L = CFM x .69 x ΔG			71.5	22.6	40			
				Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
							VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads												
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =								0.46			5547	4041

This spreadsheet and the process behind the calculations will be discussed in greater detail in the following paragraphs. It is inserted here for reference; column and row headings and sections are important to understand for navigation as well as the research and calculations behind the process. A complete workbook of the spreadsheets used in this research can be found in Appendix A.

The first step in calculating the heating and cooling load was to research the surroundings. The residence is located in Manhattan, Kansas and experiences the following design conditions according to the 2009 ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) Fundamentals Handbook:

Summer		
	Outside Dry Bulb Temperature	97.6°F
	Outside Wet Bulb Temperature	75.6°F
Winter		
	Outside Dry Bulb Temperature	2.5°F

(“ASHRAE Fundamentals Handbook”, 2009)

These conditions are for the worst case scenario. The cooling dry bulb temperature is taken at 1% meaning that the temperature is below this point 99% of the time. Similarly, the heating dry bulb is taken at 99.4% meaning that the outdoor temperature is above this point 99.4% of the time. So, the calculated loads may happen a few times a year or once every five years; either way, the system is maxed out for peak load when it may predominantly run at part-load.

The interior thermostatic setpoints for this building are harder to pinpoint. In a residence, the occupants have control of their environment and can adjust it on a whim. This can make it hard to model the energy use of such a building because the internal temperature can fluctuate drastically. This is the case with the residence being analyzed. The residents adjust the thermostat to their liking without hesitation. When either resident feels a chill, the temperature goes up. When a resident is too hot, the temperature goes down. After speaking with the homeowner, however, thermostatic setpoints were agreed upon by what he usually sets the thermostat at, or what it is set at most of the time. This is not as accurate as a commercial building with a fixed, locked thermostat, but it is the best solution considering the circumstances. If there was more time, resources, and occupant cooperation, the occupants could have been asked to record the thermostat changes each season and come up with an average set point. But, this type of precision would require the occupants to remember to document and possibly even alter their temperature adjustments throughout the year. This would be too much. Asking the homeowner for his estimate of the average thermostatic setpoint for the heating and cooling season had to suffice. Time and patience were saved.

During the summer, or cooling period, the internal set point is usually 75°F. During the heating period, the internal set point is most often 74°F; which is higher than what would have initially been designed for without intimate knowledge of the homeowner preference. A typical commercial building might be set at 70°F or 72°F. Some people even prefer to set homes or apartments at 68°F to save money. This high indoor temperature during the cold winter months is a sign that staying warm is a priority in this household, or that the occupants are more sensitive to climate changes. The indoor relative humidity is set at 50%, though it could fluctuate more than temperature. And, lastly, the change in grains for the residence was determined using the outdoor design condition and assuming a leaving air temperature of 55°F. This accounted for the anticipated humidity of the region.

After determining the design conditions, the calculation of the building loads began. The "load" is either the cooling sensible or heating BTUh required to satisfy the thermostatic setpoints. The heat transmission loads for this residence were calculated after thoroughly researching the building envelope. The construction of each wall, roof, and door were determined from conversations with the owner and from closer inspection. The respective R-values and K-factors were found in the 2009 ASHRAE Fundamentals Handbook for each construction type. Knowing the R-value or K-factor allowed the flow of heat through the building envelope to be calculated, which will be referred to as the U-value. The U-value of a particular part of the building envelope reflects how quickly heat flows through the material from the exterior to the interior, or vice versa. A high U-value means that the construction of the envelope is poor and has little insulation against heat transfer. A low U-value represents a highly insulated assembly. The reciprocal of the R-value is used as the U-value ($R = 1/U$). When only given the K-factor, the reciprocal of the K-factor is multiplied by the thickness of the material to obtain the U-value. The following table is an example that shows the envelope construction, respective K- and R-values of each material and the final U-value of the wall

Table 2-2 Upper Level Masonry Wall U-value

Upper Level Masonry Wall		
Wall Construction	K-Factor	R-Value
Outside Air Film		0.1700
4" Stone Veneer		0.3200
1/2" Cellotex Sheathing		1.3200
3.5" Fiberglass	0.26	13.4615
1/2" Sheet Rock	1.1	0.4545
Inside Air Film		0.6800
Total R Value		16.4061
U Value		**0.0610**

This wall is above-grade and spans the length of the residence's west wall. After calculating all of the U-values, it was determined that the masonry wall differed only slightly from the walls with wood siding. But, each calculation is still shown and the other U-values for the roof, doors, and other walls can be found in Appendix A.

Once the U-value was known, the process began for calculating the heating and cooling BTUh required for the room in question. A BTUh is a *British Thermal Unit per Hour* and is a widely used unit of measure for heat transfer in buildings. Determining the area of the wall was the next step. The area of each exterior wall was found through simple measurement or through use of the floor plan supplied by the owner. The area of the room's exterior wall was multiplied by the U-value to evenly distribute the heat flow. This product was then multiplied by the difference of the worst case outdoor air temperature and the indoor heating dry bulb temperature to determine the BTUh required to overcome the heat loss through the particular wall. The heat transfer for a wall below-grade is slightly different.

If a wall is below-grade, heat loss occurs but is less pronounced. The basement walls located on the perimeter of the building experience an abbreviated heat loss compared to the walls above-grade. The heat transmission is not as significant because the earth acts as a natural insulator. The efficiency of the earth as an insulator improves as a wall extends deeper into the earth, so the loss of heat becomes less and less. Conversely, a below-grade wall does not experience any heat gain from the earth because the temperature remains constant at a lower temperature than the air above.

For this building, the basement walls are 8 feet high with the top 2 feet of the wall extending above grade. For approximation purposes, the top 2 feet of grade were considered exposed and treated as an above grade wall. Walls that extend below grade by more than 2 feet experience the smaller degree of heat loss that was mentioned above. The degree of heat loss is calculated through the use of values obtained from Table 17, Heat Losses for Below Grade Basement Walls and Floors, of the ACCA (Air Conditioning Contractors of America) Load Calculation Manual. These values have units of BTUh per square foot and are specifically for below grade masonry and concrete walls. The value to use was determined by the wall's depth below-grade, the insulation of the wall, and the winter design temperature difference between the interior and exterior in the dead of winter. In this case, there is no insulation and the winter design temperature difference is 71.5°F. The wall extends 6 feet below grade, however, and Table 17 is split into two main categories: walls 2 to 5 feet below grade and walls more than 5 feet below grade. To determine the heat loss, the variable had to be averaged and interpolation had to occur in the table to account for the foot of wall that extends below 5 feet. After interpolation, the heat loss for the room was determined by multiplying the area of the below grade wall by 7.5 BTUh/S.F. No U-value was necessary for this calculation, and the heat loss through the wall is much smaller than that of an above-grade wall. The cooling load was a little more complicated.

To determine the BTUh cooling load required to maintain the interior thermostatic set point of a room at the worst case temperature, the time of the peak must first be determined. The *peak* is defined as the exact hour in a year that the room will experience the largest possible cooling demand on the system, or the hottest hour of the year. For the room loads, the peak will be determined based on the orientation of the exterior wall(s). The composition of the wall also matters because it affects the amount of time it takes for heat to pass through a wall. The hottest hour of the year directly correlates to the sun's position in the sky; an east facing wall will experience its peak in the morning when the sun's warmth is directly upon it. The peak for each room was calculated using a series of tables from the Cooling and Heating Load Calculation book (ASHRAE GRP-158). The first step is to choose the group number that the wall construction most closely compares to from Table 3.9. With the group number known, find the cooling load temperature difference (CLTD) from Table 3.10. Match the orientation to the wall in question and select the highest number in that row within reason. The column that this number is found in is the time of day that the sun is the hottest. Using logic and experience, it was decided that the peak months for any of the orientations would be July or August. After research, the following peak times were used: a north exposed wall peaked at 6pm in July; an east exposure peaked at 10am in July; a south exposure peaked at 2 P.M. in August; and, a west exposure peaked at 5pm in July as well. With the month of the peak known, a correction number found in Table 3.12 that accounts for the geographical latitude of the building could then be added to the initial temperature difference. The final step was to add the last two correction numbers to the accumulating temperature difference found in Table 3.13 ("Heating and Cooling", 1979).

In parts a) and b) of Table 3.13, additional correction numbers are offered based on the daily range of the area; one for the inside design temperature and one for the outside design temperature conditions. After totaling the correction values for the cooling load temperature difference (CLTD), it was possible to calculate the cooling load for all sunlit walls. The CLTD was multiplied by the U-value and area of the wall to obtain the BTUh required to overcome the heat gain through the exterior wall of the particular room. Calculating the heat transfer through the fenestration of the residence was a similar process, though different tables were used.

More heat is lost and gained through the walls and doors of the house than through the ceiling. And, like the walls, a U-value had to be determined for each window type and for the door. There is one solid door for the residence (the front, main door) and two smaller back doors with inset glass. Because the solar heat gain governs, or affects the heat transfer greater than the transmission through the solid part of the door, only the glass will be analyzed. For the front door, a U-value was also calculated. The following table shows how the U-value for the solid-core door was determined:

Table 2-3 Solid-Core Door U-value

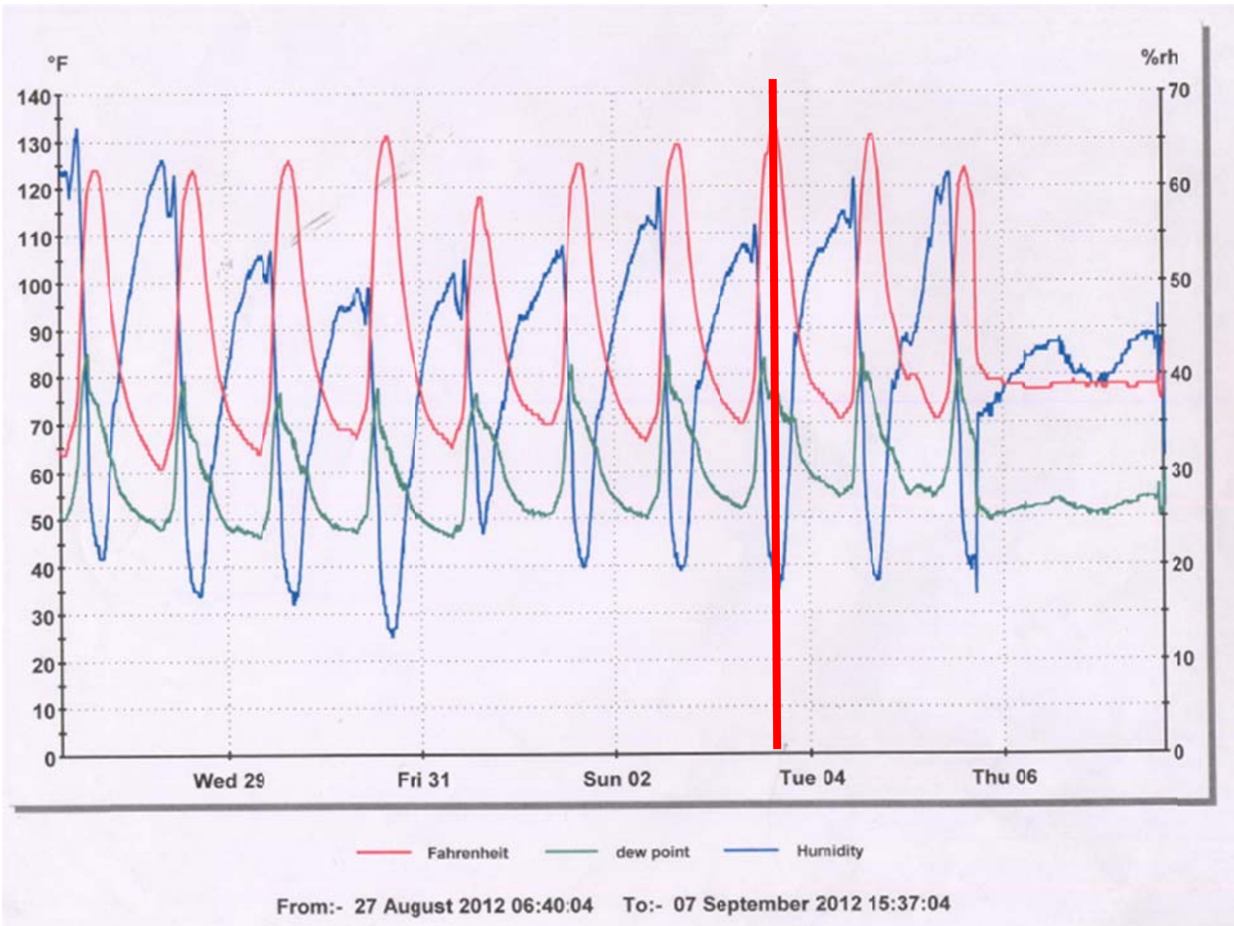
Door Construction		
Door Construction	K-Factor	R-Value
Outside Air Film		0.1700
Fir, 1.5 in.		1.8900
Inside Air Film		0.6800
Total R Value		2.7400
U Value		**0.3650**

This table has fewer elements than a table describing a wall or roof, and the thermal resistance is poor, so the U-value is high the heat transmission through the door is greater than through a wall. With the U-value determined, the BTUh heat gain or loss was then calculated by using the same process for a wall. The U-values for the smaller back doors are the same as the glass for the first floor windows and their respective table can be found in Appendix A.

The U-value for each glass type was determined from the 2009 ASHRAE Fundamentals Handbook. The U-values for windows are grouped into two major categories: summer cooling or winter heating. Worst-case situations are always used to be conservative, so, in this case, the higher U-value was used for each type of window. The windows in the vestibule are different from the rest of the house. They are strictly single pane, low emission windows with no internal shading. The U-value for these two windows is 0.79. The above grade, first floor windows are single-pane, clear, and have a storm window. Internal Venetian blinds are installed on every window and kept closed most of the time, but the glass was still assumed to be bare to remain conservative. The U-value for these windows is 0.50. The basement windows do not inhibit transmission well. The windows are clear, single pane and have a U-value of 0.81. The heat gain for windows is calculated the exact same way as for walls. The calculated U-value is multiplied by the area of glass and then by the heating change in temperature. The cooling load, or heat gain, is determined differently. No CLTD is necessary, instead the cooling change in temperature is multiplied by the U-value and area of glass as was used for the heat loss calculation. The cooling or heating change in temperature is the difference between worst case outdoor dry bulb temperature and indoor thermostatic setpoint for that particular season. The next step was to calculate the roof or floor heat loss or heat gain.

There is heat transmission through the roof and floor of this building; just how much depended on the construction. For the first floor, there will be heat gain and heat loss through the roof. There is no heat gain through the ceiling of the basement because no heat is actually transferred through the floor construction of the first level above. The insulation for the roof is actually located on top of the gypsum board ceiling; the attic is unconditioned. For the winter, the heat loss calculation is straight forward again; multiply U-value by area by heating change in temperature. For the summer, the heat gain is amplified. Heat is transmitted through the roof construction into the attic space but is “trapped” between the insulation and the shingled roof through which it just came. This is why attics are so hot on summer days; there is nowhere for the heat to go. To be as accurate as possible, a temperature recorder was placed in the attic of the Burton residence during the months of July and August. The highest temperature recorded during this time was 133°F (on August 4th) which will serve as the peak temperature for the cooling season, and therefore be the cooling change in temperature for the roof. The temperature fluctuation for the hottest 11 days analyzed can be seen in Figure 2.2.

Figure 2-1 Temperatures Recorded in the Residence's Attic Space



The BTUh heat gain from the roof is determined by obtaining the U-value, multiplying it by the area of the ceiling, and then multiplying the product by the cooling change in temperature. The U-value for the ceiling was obtained through a similar manner as for the walls. The construction of the roof has changed since the building's erection. The original construction included ½" sheet rock with 6 inches of fiberglass insulation. In the years since, additional insulation has been added to bring the fiberglass total to 11 inches, seriously fortifying the ceiling against heat gain or heat loss. The U-value of the ceiling is a very good 0.0229, and further details about the U-value calculation can be found in the appendices.

Heat transmission also takes place through the floor of the basement, but it is less pronounced when compared to the ceiling. The floor construction is poured concrete; therefore the heat loss is spread out across the floor area. No heat is gained through the slab. The total heat loss was calculated using Table 17, Heat Losses for Below Grade Basement Walls and Floors, of the ACCA Manual. For a basement floor, heat is lost at a rate of 1.7 BTUh/S.F. for a heating temperature difference of about 70°F. This factor is then multiplied by the floor area to get the total BTUh heat loss. This concluded the heat transmission calculations for the building envelope; the next step was to calculate the solar heat gain through the envelope's fenestration.

All windows and glass doors set in a building envelope experience some form of solar heat gain or solar radiation. The magnitude of the solar heat gain through the glass depends on the orientation of the building. A north-facing window will receive less direct sunlight compared to a south-facing window. This is because of the geographical position of the building and the tilt of the earth. In this case, the residence is located in the northern hemisphere near 40 degrees latitude. The tilt causes the sun's path to be in the southern portion of the sky rather than directly overhead. This also explains the larger solar heat gain that is experienced by south-facing windows (and walls). Glass orientation affects the *solar heat gain factor* (SHGF), which greatly affects the cooling load due to solar radiation. The SHGF is an estimated value used in calculating the solar gain through a glazing system using the shading factor (SF) as well. The shading factor was approximated through discussions with the homeowner and set at 0.35. Windows throughout the residence are internally shaded by venetian blinds that stay down most of the time. The SHGC was found in the ACCA Load Calculation Manual in Table 2B; Solar Heat Gain Factors for Internally Shaded Glass. Table 2A, which gives the SHGF for bare glass, was used for the vestibule glass but nowhere else. The estimated SHGF's within the tables are categorized by line of latitude, orientation, and time of day (which was considered the peak time). Depending on the room's orientation, the SHGF was multiplied by the area of the window and the pre-determined shading factor to find the sensible cooling load in BTUh. To illustrate this process, the solar heat gain calculation has been inserted for reference:

Figure 2-2 A Section from the Load Spreadsheet Showing the Typical Solar Heat Gain Calculation Process

	ITEM		AREA	EXPOS-URE	Tbl 2A,2B SF	Tbl 3 SHGF		BTUh COOLING LOAD	BTUh HEATING LOAD
SOLAR	GLASS	windows	40	N	0.35	32		448	
		doors							
	GLASS	windows		S					
		doors							
	GLASS	windows	32.5	E	0.35	164		1866	
		doors							
	GLASS	windows	32.5	W	0.35	156		1775	
		doors							
							SOLAR SUBTOTAL	4088	

The area of each window (depending on orientation) is multiplied by the shading factor and the solar heat gain factor to calculate the required cooling BTUh. No heating load was calculated because solar radiation does not increase the heat loss in a building, it decreases it. This is known as “free heating” where internal or external loads add heat during the winter months that require heating to maintain the thermostatic setpoint. The solar radiation aids the heating process and is therefore not used in the BTUh accumulation for the overall heating load.

After calculating the external loads on the residence, the next step was to figure out the internal loads affecting the cooling BTUh of the building. No heating load is necessary like in the solar heat gain calculations because the internal loads act as free heating. The first of the internal loads to be considered was the lighting.

Lighting loads for a building are typically calculated on a watts per square foot basis to get the lighting power density (LPD) when the actual watts in a building is unknown. This allows for the lighting in the room to be evenly distributed throughout the space and fully accounted for. The total watts in a room are all that is necessary for this calculation, but the LPD for each space was determined so that they could be referenced later on and compared to the model. To calculate each individual room LPD, the total wattage present in the space had to be determined. To do this, the wattage of every lamp in each room had to be recorded. Once the wattage of each fixture was known, the LPD could be determined by dividing the wattage present by the total area of the room. With the LPD known, the next step was to determine how the lighting wattage affected the cooling load in the space.

The lighting load for each room was calculated using the listed wattage installed in each space. To transform the known lamp wattage into BTUh sensible heat gain, a conversion had to take place. A single watt is equal to 3.413 BTUh for incandescent fixtures. In the case of fluorescent fixtures, 1 watt is equal to 4.1 BTUh. The total BTUh heat gain to be overcome by cooling was then determined by multiplying the total watts in a room by the appropriate factor, but the results were skewed. The cooling BTUh for lighting is for the worst possible case. The calculation shows what the cooling load would be if the lights were on all day long, which would rarely be the case. In residential homes, most occupants are energy conscious and strive to save energy, as is the case with the home in this study. This means that the lights are only on when needed; when the sun is down or if there is insufficient daylight. For room loads, this overestimation of the lighting loads is not particularly important. But, when calculating the block load and all lights are assumed to be on at all hours of the day every day, the unit can be oversized. To aid the calculation process when building the model, lighting was diversified greatly by estimating the hours of operation for a year. The break down will be discussed in further detail in Chapter 3.

The second type of internal load that affects the cooling load of the building is the occupancy. The number of people and their activity level adds to the latent and sensible heat gain in the space. This residence currently houses two people, so that is the number that it was designed for. The occupants' activity level is considered to be moderate; typical of seated, very light work ("ASHRAE Fundamentals Handbook", 2009). The latent heat gain expected is 200 BTUh per person and the sensible heat gain expected is 250 BTUh per person. The latent heat gain experienced due to people in the space is the first seen in the load calculation spreadsheet and starts its own column. The sensible heat gain from the people was totaled and added to the accumulating BTUh cooling sensible load column.

The third and final type of internal load contributor is equipment. The only equipment in the residence considered to give off significant heat gain was found in the den and kitchen. The household has one computer that is located in the den. The expected heat gain from the computer was determined by referencing the ASHRAE Fundamentals Handbook and talking with the operator. The heat gain was diversified and calculated to be 500 sensible BTUh and added to the total. In the kitchen, the equipment that contributes to the heat gain is the refrigerator, range, microwave, and dishwasher. The only piece of equipment that contributes to the latent heat gain is the dishwasher and it is anticipated to be 3010 BTUh. The rest of the equipment adds to the sensible heat gain. The dishwasher's heat gain is 1040 BTUh, and the refrigerator, microwave, and range total 3200 BTUh sensible heat gain together. When this was completed, the internal loads were known and the room loads were finished. The infiltration load next had to be determined on a room-by-room basis.

To determine room infiltration loads, the volume of each room had to first be calculated. Once known, the volume had to be multiplied by the *air changes per hour* (ACH) factor. "Air changes per hour" is a measure of how many times the air within a defined space (normally a room or house) is replaced. The ACH can be found in the ASHRAE Fundamentals Handbook and it is listed according to the outdoor design temperature and the tightness of construction. The worst case outdoor design temperature of the region is roughly 0°F (using a design indoor temperature of 68°F) and the construction was assumed to be tight. The only way to know the actual infiltration rate of a building is through conducting extensive airflow testing, while the tightness of construction is generally assumed. For this residence, an ACH factor of 0.51 was found in the in Table 5-1 Change Rates as a Function of Airtightness ("ASHRAE Principles of HVAC", 2009). The product of the volume and ACH was then divided by 60 to get the amount of cubic feet of air per minute infiltrating the building construction. To calculate the sensible heat gain and heat loss, the CFM was multiplied by 1.08 and then the respective change in temperature. To find the latent heat gain, the CFM was multiplied by 0.69 and then the cooling change in grains. The infiltration through the perimeter of the doors was calculated in a similar way. The only difference was the ACH factor and the area, which was the linear footage of the perimeter. After the infiltration was calculated for each exterior room, the room loads were completed. No ventilation is required in residential homes where the windows are operable, so further calculations were not needed. The end result of the room load presented the cooling latent and sensible BTUh and the heating BTUh. The "tons" data box represents the total cooling BTUh divided by 12,000.

The second part of calculating the heating and cooling loads for the building was determining the block load. The block load is required to size the HVAC unit for the building; important information for building an energy model. So, because the design conditions remain the same when moving from room loads to block loads, the first step for calculating the block was to determine the building peak.

Based on inspection, the peak of the entire building was calculated to occur at 10 A.M. in the month of July. This was decided because there are a number of windows on the east wall of the residence and the total area of glass directly relates to the peak of the building. The large amount of solar radiation expected through the east-facing windows would govern over any heat transfer that occurred through the other walls of the building. There are windows on the north-, south-, and east-facing walls, but the area of the glass on each wall is not greater than the east wall, and therefore not expected to affect the peak time.

After the peak was decided upon, the heat transfer through the building envelope was analyzed as a whole. To start, as usual, the heat loss and heat gain through the walls of the residence had to be calculated. The total areas of the above grade and below grade walls were inserted into a new load spreadsheet like before according to their respective orientations. The same U-values calculated at the beginning of the process were used for their respective wall constructions as well. The heat loss (in BTUh) was calculated using the same process as before. Below grade wall areas were multiplied by the heat loss factors (BTUh per square foot) in the ACCA Load Calculation Manual to get the heating load required to heat the basement in the winter. What separates the block load from just being the sum of the room loads is how the peak affects the CLTD and sensible cooling load. New CLTD's had to be calculated for all above grade walls of the building using the peak of 10 A.M. in July. This lowered the cooling demand on the system compared to the sum of the room loads.

Next, the heat transmission through the windows, doors, floor and ceiling had to be calculated. This process did not differ from the process that was used to calculate the room loads, except that the areas of each were the grand total for the entire building. These areas, or were multiplied by the assigned U-values and then the temperature differences to get the cooling or heating load required. This completed the block transmission loads and it was now time to calculate the block solar heat gain loads.

The solar radiation calculations were exactly the same as for the room loads; the block load was actually the sum of the solar loads from all of the rooms. The same goes for the lighting block load, though the wattage is the extreme. Again, the lighting load was calculated using the listed wattage installed in each room, which is the absolute worst case. A house will never have every light in every room on for an extended period of time. After speaking with the homeowners, this assumption was confirmed; they are energy-conscious people. The occupants strive to turn lights off when rooms are unoccupied or lit well with daylight and are always trying to save money. So, the actual lighting load will be extremely low compared to the calculated, and there is a good chance that no lights are on during the peak time of 10 A.M. in

July. Therefore, the heat gain from the installed wattage at the peak time in each room was not included in the block load calculation. The people and equipment were the last factors to account for in the internal loads. The residence was designed for 2 people. The only equipment considered to affect the load was a computer, the refrigerator, range, and dishwasher. The heat gain from these final factors matched what was used in the room loads and completed the internal heat load calculations.

To finish out the system loads, all of the infiltration from each room had to be accounted for in the block. The infiltration CFM's for each room were totaled and inserted into the block spreadsheet and added to the accumulating cooling latent, cooling sensible, and heating load totals. Once the total CFM of infiltration was known and the BTUh heat gain and heat loss were calculated, the block load was finished. No ventilation loads were calculated because no ventilation is required in a residence with operable windows. The total block cooling load for the system was found to be 4.34 tons. This number and the issues that surround it are analyzed further in the next section.

Problems with the Loads

The HVAC system in the residence is a furnace with direct expansion (DX) cooling. The size of this unit is 3-tons. The calculated block load was 4.34 tons; a cause for concern. However, when the analysis is broken down, there are few flaws with the process and calculations that stand out.

The first element considered was the interior lighting. To see just how much the block load was inflated, the loads were run again without any lights on during the peak time. In the original block load, the incandescent heat gain was 2008 watts and the fluorescent heat gain was 880 watts at worst-case. Removing lighting from the load calculation lowered the block load significantly.

Most people are concerned with saving money. Energy is essentially the same thing as money, and lighting a home takes energy. The occupants of the residence in question are like most people and try to save energy and money. Lights are turned off when they leave a room and daylighting is utilized when possible. Bedrooms that have been vacated by sons and daughters years ago remain unused, and the lights remain off. These “spare” bedrooms are now only used in the event of guests staying the night. But, even with visitors, the few hours that the lights will be on for a weekend or week will barely affect the anticipated lighting load for a year. In fact, a room's lights being on for 100 hours in a single year only accounts for a little more than 1% of the annual lighting. The lighting heat gain in a residential application really is miniscule compared to commercial applications that have lights fully on for 10 hours a day, and no lighting is utilized during the peak load.

The ACCA Load Calculation Manual states that the shading factor (SF) for commercially available products could range from 0.25 to 0.70 for field applied films and coatings. The initial shading factor used to calculate the solar heat gain in the residence was 0.55; a middle number that favors the higher side. But, the subsequent heat gain was very large and yielded a large sensible cooling load. After talking with the owner, it was decided to use a shading factor of 0.35; the windows are shaded most of the day and have internal venetian blinds that remain closed a majority of the time. Reducing the shading factor lowered the sensible cooling BTUh to a reasonable number and was approved by the homeowner.

Reducing the lighting and shading factors reduces the required cooling BTUh for the building. The block load went from 4.34 tons to 3.47 tons; a pretty significant reduction. Having a unit that is 0.47 tons undersized is defensible; especially for a residential building. Predicting the heating and cooling for a house is not difficult when extensive knowledge of the house and its use is known. Certain rooms in the house are used every day and at length while others are neglected and barely frequented. The way to discover what rooms are used most often is through discussions with the owner and the occupants. Some rooms are quickly marked as priority and high-use and some rooms are barely used and defined as such. But, this knowledge only helps the designer understand what is happening inside of the house; it does not change the calculation process. The room and block loads are still calculated based on a worst-case scenario.

The unit is sized based on the hottest and coldest days of the year; data which comes from the ASHRAE Handbook and is based on 30-year averages. Weather changes, and some winters are milder and some summers are harsher than others. A unit may not have to supply for the coldest or hottest day designed in an operational year because it may not occur. If the worst-case scenario does occur, then it may only happen once a year. If the unit is undersized, then, at most, only a few days in a given year will not be supplied sufficiently by the HVAC system.

Therefore, undersizing a unit is acceptable given the amount of variables that went into designing for the worst-case scenario.

Every room in this house is not used and some rooms are used only sparingly. This makes the conditioning of these spaces less of a priority because a space is conditioned for the benefit of the occupant, but an occupant has to be present. If no person is present in a cold or hot room, it doesn't really matter that the room is cold or hot. It's a non-issue. This makes the thermostat location important. If centrally located, like is the case for this residence, the HVAC unit is only running to overcome the heat loss or heat gain that is "felt" by the thermostat and rooms in the center of the house. Rooms located on the exterior, or possibly a far corner, away from the thermostat may be a few degrees cooler or warmer due to the fact that the thermostat is not reading the demand for temperature. Therefore, the unit is not conditioning the whole building. The basement rooms will definitely experience different conditions compared to the ground level, especially in the winter, but most of the rooms are rarely used. The basement living room, however, is used often and the thermostat is probably adjusted when occupied. During the winter, the thermostat is probably set at 74°F or higher to account for the cooler outdoor temperatures. But, most of the rooms in the basement are rarely used for an extended period of time, and are basically isolated from the central, above-grade rooms of the house. If these exterior and isolated rooms are never occupied, then the conditioning of the space is not that important, or the load is negligible and does not affect the block. This means that the unit being undersized is not as big of a problem as initially thought upon first glance.

The block cooling load of 3.47 tons is misleading. The less-frequented basement could account for a ton of the block when in reality only the living room is being used. The same thing goes for the heating load. The below grade walls will experience a large amount of heat loss due to the large amount of surface area in contact with the earth during the winter months. The block was designed for the worst possible case that the unit will rarely see. Because this peak will not be reached but a few days in a few years and because of the skewed occupancy density discussed previously, undersizing the unit is not a major cause for concern. This is because many of the rooms in the house are unoccupied and located away from the thermostat and higher-use areas, and, therefore, not placing a demand on the system.

The load calculation method used for this analysis was the CLTD method. This method has since been considered outdated by ASHRAE. The CLTD Method is still recognized by

ASHRAE, but it is not the preferred method. The 2009 ASHRAE Fundamentals Handbook recommends the use of the Residential Heat Balance Method or the Residential Load Factor Method. These methods and the CLTD Method use the same process for the heating calculations, but they differ in cooling. Commercial load calculations (like the CLTD Method) are based on fixed thermostatic setpoints and usually anticipate more cooling than a typical residence would require. Therefore, the high cooling for this residence can be explained.

Chapter 3 - Building the Model

To intimately analyze the building and predict its performance, an energy model had to be created. This simulation program is a computer-based, mathematical model of some aspect of building performance based on fundamental physical principles and engineering models. The software is designed to emulate the dynamic interaction of heat, light, air, and moisture within the building to predict the energy and environmental performance as it is exposed to climate, occupants, and conditioning systems (Dru Crawley Presentation, 2003). An energy model uses typical load calculation variables such as solar heat gain, lights, equipment, and people to model a building's energy use, much like the running of heating and cooling loads that were described in the previous chapter. But, a simulation program is much more comprehensive and the "load" in this type of building can only be solved with a computer. A single simulation can run a model using 10,000 variables against weather data that can predict the energy use by month, year, and even hour. The heat balance equation can actually be solved at each time step during the year. As time progresses, information from each previous time step becomes a system input. The heating, ventilating, and air-conditioning (HVAC) systems provide cooling and heating to the space as called for by the thermostat, and their performance (energy use) is simulated using the inputs. The energy modeling program simulates energy use based on the data inputted into the system.

The typical data inputs for most simulation programs consist of weather data, construction type, building geometry, and HVAC system details. The lighting, additional equipment, utility rates, and local code baseline are also typically included in the construction of the model. With the data inputs completed, the program can run simulations and output data that is important for the design of any building. Typical data outputs include space conditions, surface temperatures, humidity levels, HVAC parameters, and total energy consumption.

The purpose of running such simulations is to project costs for the homeowner. Predicting how much energy is used each month can estimate the cost of utility bills. But, just predicting the cost is not overly beneficial; homeowners would probably prefer not to know if nothing can be done about it. Alas, that is the ultimate purpose for creating an energy model: improving design. Improving the design of a building means aiding the efficiency of the HVAC systems and decreasing utility bills. With a computerized model, the envelope construction of a building can be dissected and experimented with. The insulation and fenestration can be improved in the model, and the effects can be noted. Windows can be exchanged for more thermally resistant glass with better glazing or more panes. More insulation can be added to the wall cavity to prevent heat transfer. Door construction can be enhanced. The subsequent energy used by the systems after such alterations can be monitored and compared to what is being used by the current system. Utility bills can then be compared and money savings can be documented. The initial costs of each item or items must be known prior to alteration so that the total costs can be compared. The point of this analysis is to know if improving the design is worth it.

This is the goal of the report; to provide homeowners with documented evidence that supports changes in building envelopes and their systems that will improve the design of a residence and decrease utility bills; or more importantly save them money. The cost of improving elements of the construction will be included in the research so that the complete savings are known. The cost of the installed element and the proposed element may be just as important to the homeowner as the potential energy savings it could provide. All tested elements and results were noted; positive and negative. This report strives to be unbiased and state facts. To obtain these facts and data, an energy analysis was performed on the building using the modeling interface eQuest.

Why eQuest?

The program eQuest is widely used in the consulting engineering world for energy modeling. It is very user-friendly and accepted as an industry standard when it comes to whole-building simulation analysis. There are many programs that are capable of doing some level of energy analysis, but one of the strengths of eQuest is that it can analyze an entire building throughout the design process. It is also very easy to navigate and explore energy performance of design concepts incorporated in the model. The inputs are designed to produce outputted data that can be used for energy analyses.

EQuest has been tested according to ASHRAE Standard 140 - 2007 Building Thermal Envelope and Fabric Load Tests and is currently based on Title 24 and ASHRAE 90.1 Energy Standard for Buildings except Low-Rise Residential (2004). Now, there are two obvious problems with this: the software lags behind the current code which was updated in 2010 and does not apply to residential applications. But, the program inputs are adjustable and can be updated with values that meet the current code; ASHRAE Standard 90.2 Energy-Efficient Design of Low-Rise Residential Buildings (2007). In this case, however, most of the details of the construction and systems are known so that the exact information can be inserted into the model to gauge the anticipated energy use.

Evaluating the Residence's Current Performance

Before creating a model, information about the residence's current performance had to be obtained so that a comparison could be drawn. This was done through obtaining and examining the home's utility bills for the electricity and gas use for the past 6 years. Analyzing these bills provided information that was vital for the creation of the energy model.

Retrieving the utility bills was much easier than anticipated. The homeowner had kept hard copies of all bills dating back several years in a single file. So, electric bills from Westar and natural gas bills from Kansas Gas Service dating back to January 2006 were collected and chosen as the data set. The electric bills listed the total kilowatts used during each month and displayed the cost of the services provided. Taxes and service charges were included in the bill as well as a franchise fee that was incorporated over the last year of the data set. The total, or end, cost was what was used to determine the $/kWh rate for the month. The end cost was used so that all money could be accounted for and the rate could be modeled in the simulation when it came time. The rate for each month was calculated so that it could be compared to the other months, but also so that the average electric rate could be determined from the entire set of bills after all of the data was entered into a spreadsheet.

The natural gas bill listed the gas used by the system in one thousand cubic feet (MCF) and also listed the cost of the service provided each month. Like with the electric bill, taxes and service charges were included in the bill. Again, the total cost was used so that the gas rate could be modeled in the simulation. The rates for each month were calculated and then totaled so that an average rate could be deduced. But, first the MCF had to be converted to Therms for convenience in the model. With 1 MCF being equal to 1.027 million BTU's, the gas MCF was converted into BTU's and then Therms (with 1 Therm being equal to 100,000 BTU's). When the monthly Therms were known, the data could be easily compared and analyzed. The rate of $/Therm could then be used, even though the BTU usage was all that was needed to compare data within the model. All of this data was inputted and analyzed through the work of an Excel spreadsheet for simplification. This spreadsheet can be found in Appendix B for reference.

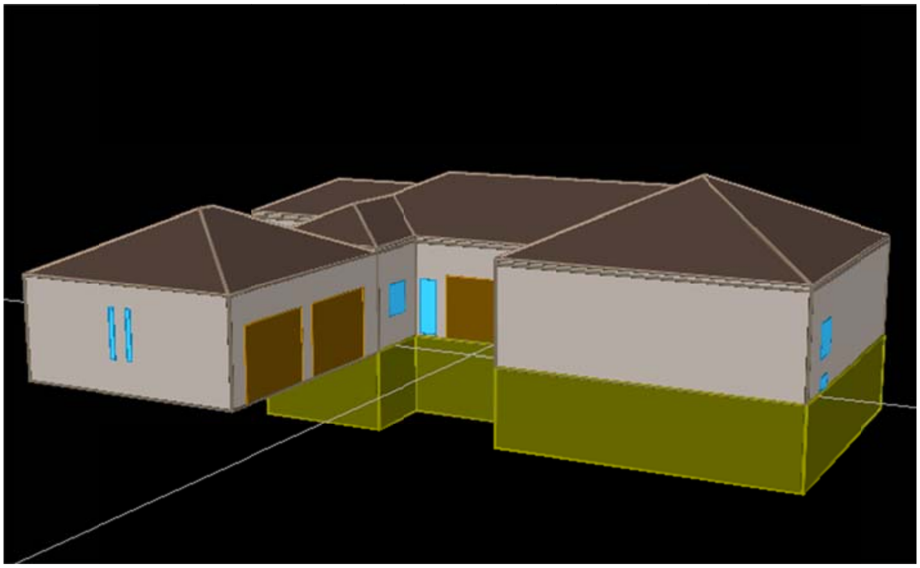
Using the spreadsheet, the monthly electricity and gas usage was averaged. The utility bills were averaged as well to get a typical cost per month. Averaging the bills in this way provided data that displayed what a typical year would use in terms of energy and cost in terms of utility bills. Having this data available was a very good reference to have when creating the model and allowed the actual rates to be inputted into the simulation program. It was also a good aid to have when comparing the monthly energy uses between the simulation and the actual bill. Determining the average rate for the electricity and gas profile was a complicated matter that will be discussed later.

All of the data compiled is just an average and depends on the weather and accuracy of the model. There are many assumptions that had to be made within the model and changes that had to be made to get an accurate representation of the building. It is important to understand, however, how this data analysis depends heavily on the weather. The climate outside effects the cooling or heating demand on the system within the building. A mild winter or a cool summer can lead to the outliers seen above, or throw off the averages entirely. Therefore, multiple years had to be analyzed in an attempt to get a value that might represent a typical summer. With the actual energy use data categorized and documented, a model could then be created and conclusions could be drawn.

Building the eQuest Model

To begin building the energy model, eQuest had to first be downloaded from the DOE website. After installation, eQuest was opened and the building process started in the Schematic Design Wizard. The Schematic Design Wizard is most often used for the earliest design phase of small, simple structures with simple schedules and smaller HVAC systems; all criteria that seemed to fit for a residential building. This wizard is also the easiest to navigate and designed for simpler structures compared to the Design Development Wizard. A 3-Dimensional view of the energy model can be viewed in Figure 3-1.

Figure 3-1 3-Dimensional View of the eQuest Model



Once a phase wizard was chosen, the construction of the model could begin. The Building Creation Wizard is the navigation interface that allowed all details of the construction and systems to be inputted and adjusted at any time. The first screen in building the model was very basic; the project information had to be inserted for organization and reference. The name of the project and building type were the very first pieces of data required. The building type was considered Multifamily, Low-Rise (exterior entries). There was not an option for straight "residential" at this screen, though more appropriate options could be found later for most parts of the model. It is important to note, however, that some areas could not be adjusted to accommodate every aspect of a residence.

No ventilation occurs within this residence, but the model required the use of ventilation fans. The presence of these fans skewed the electrical use to the point where the miscellaneous loads had to be reduced to account for this. The model does not provide accurate lighting power density defaults and assumes that all spaces will have lights on during "operation".

After filling out the general information, the building location and jurisdiction had to be specified. The location set was limited to California, Canada, user selected, or all eQuest locations. The building for this project fell into the "all" category and the geographical location of Manhattan, KS was inserted. The jurisdiction was changed to "other" for the reason stated previously; the code this building would be analyzed by is ASHRAE 90.2 for residential buildings, which was not an option in eQuest.

The last information required on the initial “start-up” screen was the utility rates and “other data” section. The utility rates are custom, so they would be inputted later. The analysis year of 2012 had to be specified along with the hourly end-uses profile option. The second screen was just defining the season. This building is occupied throughout the entire year, so there is only one season. A few holidays are observed to simulate the family going on vacation; such as a trip to the lake, which they do from time to time.

The third and fourth screens involved the utility company charges for electricity and gas use, respectively. The actual rates were concluded from the owners’ utility bills on record. The yearly rates were averaged in the spreadsheet and inputted into the model. The rate was chosen to be a uniform charge for the entire year in each case, but there was a glaring issue with the gas rate that was apparent at once.

If an average utility rate for the entire year was used, the results would be skewed. During the summer months with little heating (for the water heater only), the rates are high because of the lack of use. The summer sees such little gas use that the rate appears very high because of a small sample size and because of the flat fee charged for service; the gas rate is about $3 for approximately 6.0 Therms. The low gas bill is divided by a comparably large amount of Therms and leads to an inflated rate. These outliers during the cooling months can seriously throw off the realistic rate that remains constant throughout the winter. So, instead of using an entire year average, it was decided to split the rates into two seasons: the cooling and heating seasons. This balanced out the rate by not including the inflated summer rate in the average and keeping the rate closer to the actual rate used by the utility company for the typical heating months. In reality, the house does not use very much gas at all in the summer; typically the only gas usage is for the water heating. The house does not need nor use space heating during the summer months, not even in the basement. But, eQuest calls for space heating during the summer months; possibly for dehumidification and reheat purposes. However, this is absolutely not the case. The owner never turns the heat on in the summer on principle if nothing else. So, the high rate for the actual utility bills is negligible; there is little gas being billed. But, in the simulation which has a higher gas use than what is actually happening, the higher rate has a greater effect on the utility bills. The much higher rate leads to a bill that is too high and skewed when compared to the data from the other months, clouding the projection. It is because of this that the rates were split up. This misrepresentation is not a large problem if the model is perfect and uses the exact amount of gas that the actual building does. The model therefore is accounting for more energy use than what is happening and the yearly money total is inaccurate; by close to $150. But, the model cannot be dissected and altered to stop the summer space heating, it can only be justified.

To avoid such this large discrepancy, or at least moderate it, an average was used for the electric and gas rate. The average of the monthly kilowatt and MCF use was tallied in the utility bill spread sheet located in Appendix B. The average cost of each monthly bill was included the spreadsheet and converted into a $/kW in the case of the electricity use. The monthly rates were then averaged and a yearly rate was determined. Likewise, the same was done for the gas rate, only with the total Therms used in a year. The model then showed that the projected cost for electricity in a year was equal to the actual average. The estimated cost of gas from the model was about $1 more than what was actually charged. These numbers are very reasonable and set a good base point. Improvements made to the model will be gauged on how much money is saved annually, so this approach is desirable. The yearly cost is what is most important for this research project because the annual savings are what the homeowner cares about most.

After setting up the general building information and utility rates that make up the first group of screens, the next part of the wizard is for general shell information. Shells in eQuest represent different sections of a building, such as separate floors or areas served by different HVAC systems. Three different shells were created for this residence: one for the first floor, one for the basement, and one for the unconditioned garage. The first floor and basement are both on the same HVAC system, but the fact that the basement is below grade seriously affects the construction and subsequent heat gain and heat loss of the walls. So, when creating the shells, the first screen is for the basic information. The building type [Multifamily, Low-Rise (exterior entries)] was again inputted after labeling each shell, except for the garage. The garage building type was inputted as storage, unconditioned low bay. Exact site coordinates for the building were specified and set at the origin 0, 0, 0. The total area of the building was also inserted into the proper data box; despite being the wizard for the first floor only. This is for the area allocations that will take place later in the model. It was also here on this screen that the floor was identified to be above grade, with the shell having one floor above grade and 0 below. The last options on this screen required the shell multiplier, which is 1, and whether or not daylighting controls were being utilized, which is no.

The second screen of the shell editor was for laying out the building footprint. The building orientation was identified by selecting plan north as west. The first floor and basement drawings were provided by the owner, but to be imported into the model, a rough sketch of the outline had to first be created in AutoCAD. With a CAD file of the floor plan, the shape of the footprint could be customized in the model. The "custom" option was therefore selected for the footprint shape and a "blank slate" was chosen to start with. Then, the CAD file that was previously created was imported and the shape, or extents, of the building were traced to match the floor plan of the first floor, basement, and garage. After defining the footprint, the zoning pattern was customized as well; the entire building, except for the garage, made up one zone. With the footprint and zoning identified for each shell, the area per floor was automatically generated based on the scale of the drawing.

The next step for the footprint screen was to define the floor heights of each shell. The actual floor height of both of the floors (shells) is 8 feet. But, because the basement wall actually extends two feet above grade, the first floor and garage walls had to be adjusted to account for this extra exposure. So, the height of the first floor and garage wall, or floor-to-floor height, had to be specified as 10 feet instead of the actual 8. This is not ideal, because the heating loss through the basement walls could be abbreviated due to the shortened height of the wall. Or, the additional feet of the above grade wall will increase the insulation and skew the energy use results. But, this was the only way to manipulate the model to include the intricacies of the wall construction, so the basement wall was kept at its actual height of 8 feet. Doing this allowed the model to account for the wall heights at the floor construction an attic as well.

The floor-to-ceiling heights of each shell remained the same as the floor for simplicity, but there is an attic above the first floor and the building does have a pitched roof, so the appropriate boxes were checked. For the roof and attic details, the insulation is located on the attic floor and the pitch of the roof is 25°. The attic height was inserted as 6 inches above the top of the above grade wall, which seems small, but the roof peaks and has a height of several feet at the center of each peak like a normal attic space. The actual house has an overhang of 1 to 3 feet depending on the side, but the model prohibits an overhang from being inputted for some reason. But, the height of the overhang did not shade the windows in most cases. The overhang only covers the windows on the northeast corner of the house, the rest are exposed or treated as exposed for the worst-case scenario. So, to account for lack of overhang, the window construction included a shading factor that reflected this. Furthermore, if a similar house was being analyzed for future improvements, an overhanging deck may not be present to shade the windows on any façade. So, the windows only the shading coefficient was adjusted. No roof information was included for the basement shell.

The next step in creating the shells was probably the most important; defining the building envelope constructions. The third screen was devoted to the roof surfaces, above grade walls, and below grade walls. The construction of the roof is a standard wood frame with brown, medium light shingles. No insulation was located on the actual roof. Instead, the insulation was inputted on the next screen, but that will be discussed later. The above-grade wall construction for the first floor and garage shells consists of wooden 2x4 studs located at 16 inches on center. The exterior finish is classified as wood/plywood with a color that is 'Medium' (abs=0.6). The calculated R-value was 15, so the important thing was that the insulation inputted into the model totaled 15 as well. The exterior insulation was selected to be ¾ in. fiber board sheathing (R-2) with additional R-13 batt insulation. No interior insulation was necessary.

The floor of the first level is over the conditioned basement and the exposure was assumed to be adiabatic (no heat loss or gain). The construction is 1 in. plywood/underlayment and there is not exterior, interior, or cavity insulation. No concrete cap is used, but there is carpet with a fiber pad. The infiltration rate, however, was not something that could just be inspected.

The tightness of construction is something that is usually assumed and many buildings are claimed to be built tighter than they actually are. The only definitive way to determine how tight a building is constructed is to run a blower door test on the building to pinpoint the infiltration rate. A blower door test takes numerous hours and resources that are often times not readily available. It is for this reason that the infiltration rate was treated as the variable for the gas use, or heating condition. The infiltration rate was increased or decreased to get a model that matched the actual home (according to utility bills).

When running the load calculations by hand, it was assumed that the ACH was 0.5; a value obtained through conversations with homeowner and various professors at Kansas State University based on the assumed tightness of the envelope. The ASHRAE Principles of HVAC Handbook also recommended that the ACH be 0.51 for a tightly constructed building according to Table 5-1 Change Rates as a Function of Airtightness, but again, the tightness of construction is just an estimate. The eQuest model default lists the ACH as 0.4, so this number was used initially.

After creating the entire building in eQuest, the heating for the building came out to be higher than anticipated. So, the necessary heating for the building had to be reduced to get a total that was close to the actual building usage. One of the few ways to adjust the model's heating demand was through changing the ACH. If less winter air was entering the building, then the system would have less work to do to provide the necessary natural gas heating. It was therefore treated as the variable for the gas consumption. To get a model that was as accurate as possible, the ACH was calibrated and decreased slightly to 0.36 to bring the total heating BTU's extremely close to the annual utility bills; within $1. This ACH would make the construction tightness better than what eQuest sets as the default infiltration and better than what the ASHRAE Principles of HVAC Handbook considers tight (0.51). This is reasonable because this particular residence was thought to be built very well and tight for the year it was constructed in. Because a blower door test was not conducted on the building, treating the ACH as an adjustable variable allowed the model to be calibrated to reflect what was actually happening in the home. And, in the end, the heating variable was not adjusted much at all. The variable for the cooling and kilowatt usage will be discussed later.

For the basement shell, no roof surface was inputted because there is no exterior exposure. And, obviously, no above grade walls would be present for the below-grade basement. The ground floor is in contact with the earth and entered in as such for the exposure. The construction is 8 inch concrete with no perimeter insulation. And, the interior finish is carpet with fiber pad. The below-grade walls themselves are constructed of 8 inch concrete with a half inch of sheathing; good enough for an R-value of 1.3, but not capable of being entered into the model.

The fourth screen was where the ceiling insulation discussed earlier for the first floor shell was added. The insulation is located on the top floor ceiling (below the attic) and the R-value total was calculated to be R-42. To get this exact number, the batt insulation of R-38 was selected from the first drop-down menu and the R-4, 1 inch polystyrene rigid insulation was selected from the second. The interior finish of the residence's ceiling is drywall for all shells, and the framing is standard wood. No batt insulation exists for the basement shell, so none was entered into the model.

The fifth screen in the model was for the exterior door construction. There are 3 exterior doors to the first floor shell, with 2 of them being glass, and the two large garage doors. The glass doors were just considered windows because the solar heat gain would be more specific and the infiltration was covered earlier with the air changes per hour factor inputted into the model. The door type and orientation of the main, first floor door had to be inputted into the model; the door is opaque and faces west. The size of the door is 6' – 8" tall by 3' – 0" wide, and the construction is wooden, solid-core flush, and 1 – 3/8" thick. For the garage door, the type "overhead" was selected and the construction was chosen to be insulated steel. The exact locations of the garage and first floor doors were measured and placed accordingly into the model on the next screen.

The sixth screen of the shell editor is devoted to the exterior windows and, because no windows are capable of being inputted into the basement shell, this screen only applied to the first floor and garage. The first adjustment option was for the window area specification method. The "percent of net wall area (floor to ceiling)" method was chosen for the window area calculation. The next step was to describe the window types present for the building. There are 3 types of windows used in this building, but with 1 of them being for the vestibule only, only 2 types were used in the model for simplification. The type of window depended on 1 factor: whether the window was for the first floor or basement. The first floor and garage windows are single pane clear with 1 storm window on the outside; they have a U-value of 0.50. The basement windows are single pane and are constantly internally shaded; they have a U-value of 0.81. The first floor window frames are wood/vinyl and operable while the basement windows have aluminum frames and are considered fixed. The shading coefficient was adjusted to be 0.35 for both windows. This factor was decided on early in the process through research in the ACCA Load Calculation manual and through talks with the homeowner. The model could not replicate the overhang, or eave, of the roof, so the shading of each window had to be balanced somehow. Lowering the factor was determined to be the best course of action for accounting for such an error in the model. Such a reduction, however, affected the space heating in the residence and will be discussed later. Furthermore, for future alterations and enhancements, the shading coefficient remained constant throughout the analysis process to get accurate readings, and because the overhang and subsequent shading would not change.

As stated before, the first floor and garage windows are wood/vinyl and operable with a 1.5 in. frame. The basement windows are aluminum and fixed with a 1.5 in. frame as well. To place the windows (and door) in eQuest, the "custom window/door placement…" tab had to be utilized. After clicking this option, the windows could be manually placed on the correct wall faces and sized accordingly. The basement windows had to be placed at the lower edge of the first floor because of the 2 foot protrusion noted earlier. This did not alter or skew the system outputs or energy use because it was just important that the solar heat gain into the space be accounted for; no matter what room or shell it was taking place in. The annual energy use and utility bills were later analyzed on a whole-building basis, not room-by-room.

The next screen, Screen 7, was for the window shades and blinds. The exterior window shade section would have been useful if the program could have modeled it correctly, but unfortunately, eQuest would not allow an overhang on this building. The actual home has an overhang on all sides out to 3 feet in some areas, but the program settings would not allow it. After discussion with the homeowner, it was decided to design the model without one and go with the extreme worst-case situation in which the sun shines directly through all windows of an exposure. So, no overhangs or fins were inputted into the model. Window blinds or drapes, however, were inputted. Venetian blinds are present on almost all of the windows so "vertical blinds" were selected from the drop down menu. Some windows do have fabric drapes within the house, but they are scarcely used. EQuest also allows the user to choose what percentage of the time the blinds are closed. For this case, the blinds were assumed to be closed 50% of the time when occupied and 80% of the time when unoccupied. These values are somewhat conservative because in reality the blinds are probably kept close more than this throughout the year, with the exception of the sun room that has its blinds open most of the time for natural daylighting. And, because no windows could be inserted into the basement shell, no shades were inputted into the basement shell.

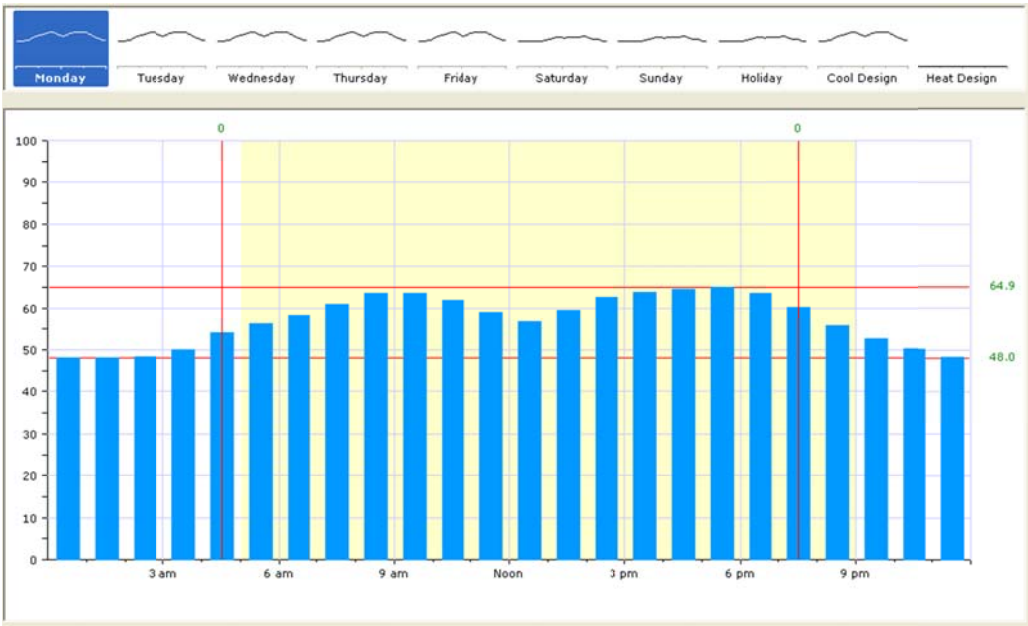
The eighth screen was devoted to roof skylights, but in the case of this building there are none. So, Screen 8 was not utilized in this model. Screens 9, 10, and 11 were not used either. Screen 9 was the next eQuest screen that required data to be inputted into the energy model. The ninth screen asked for the building operation schedule. Being a residential building, this house is in operation throughout the entire year. The actual use was defined in the model as "24-hour operation, low-use" because one of the occupants works during the day while the other occupant stays at home, though tries to get out of the house often. The difference between "typical" and "low" use in the model was not significant in the output data summary sheet, but it did favor the low end, so that is the justification of using the "low-use" option. The daily "operating hours" had to be selected as well, even though the building is defined as 24-hour operation. For this building, the operating hours were chosen to be when the occupants are awake. After polling the occupants about their sleeping habits, the operating hours for all shells were chosen to be 5 A.M. to 9 P.M for the weekdays and 8 A.M. to 9 P.M. for the weekends.

The next screen was where the area allocations were inserted into the simulation. This is important because it allows the model to intuitively create defaults and simulate energy use in certain areas of the building based on the activity level or usage of the area type. Lighting, refrigeration, power, etc. can all be inputted on a per square foot basis and distribute the respective load throughout the residence. The first floor has 5 different area types: residential (single family), storage (conditioned), restrooms, kitchen and food preparation, and corridor. The residential area type dominates; taking up 64.6% of the first floor, or shell area. The storage area was devoted to closet-type spaces and only accounts for 3.9% of the shell area. Restrooms account for 6.7%, the kitchen accounts for 12.4%, and the corridor area type takes up 12.4% of the first floor as well. The garage, on the other hand, only has one dominating area: residential (garage). So, 100% of the area was allocated to this type. The below grade rooms also had to be inserted into the model for as a part of the area allocations.

The basement has 5 different area types: residential (single family), storage (conditioned), laundry, restroom, and mechanical/electrical room. The residential type accounts for 66.2% of the basement. The laundry room takes up 13.8% of the below-grade shell while the storage area type only takes up 1.8%. And, 15% and 3.2% are allocated to the mechanical/electrical room and restrooms, respectively. Also, because each room is below grade, the "below" checkboxes were selected for each area type.

The design max occupancy also had to be accounted for on the thirteenth screen. For the first floor, the design max occupancy was manually adjusted to account for 2 people in the shell; the total number of people that live in the residence year-round. The design ventilation rate (in CFM/per person) for the garage was also manually adjusted to 0 because no mechanical ventilation occurs in the system. For the basement area, the design max occupancy had to have at least 1 person inputted because of eQuest's parameters, so 1 person was entered into the model. The total number of occupants was now at 3, but it was left to simulate a conservative scenario in which guests, children, or even grandchildren could occupy the home. The occupancy profile by season was set to "EL2 Occupancy Profile (S1)" to simulate a typical activity level and can be seen in Figure 3-2. The ventilation rates for each area type were then reduced to zero in all of the shells because no outside air was used to condition the house.

Figure 3-2 Occupancy Profile for the Residence's Area Types



The house was built to meet code standards in 1970 and, with operable windows, natural ventilation can be utilized during mild days. But, the simulation's outputs show the use of ventilation fans in the model. It may expect that not all spaces have an exterior window or door. This will be analyzed further later on.

The fourteenth screen in the model required the zone groups to be defined. In this case, there is only 1 system and therefore only 1 zone. On Screen 14, the HVAC system that serves the first floor and garage shells was selected from a drop-down box; which was labeled "HVAC System." For the garage, the "unconditioned" option was selected and assigned to the shell. Because there is only 1 system, this screen was very rudimentary and easy to interpret. There was also a check box that indicated whether or not the shell was conditioned, which was yes in this case (and most others). The "zone group details" button was located on this screen to define any exhaust taking place in the shell. There are no exhaust fans in this residence, but if there were, then the power and flow of the fan would be defined as well as the motor efficiency of the fans. The area of each room type had also been calculated in square feet on this screen using the area allocations from the previous one.

The purpose of the fifteenth screen was to assign non-HVAC end-uses to the model. The anticipated interior end-uses that contribute to the room loads are interior (ambient) lighting, office equipment, cooking equipment, miscellaneous equipment, and self-contained refrigeration. The only anticipated exterior end-use is domestic hot water and the equipment was modeled using a seasonal profile readily available in eQuest. As far as laundry facilities, there is 1 washer and 1 dryer. The washer type, "vertical axis" was selected from the model's dropdown box and the dryer is fueled by electricity and inputted accordingly. The "loads per unit per week" was a number discussed with the occupants and a value of 3.5 was agreed upon. The next step in the process was to input the exact W/SqFt data into the appropriate sections of the following end-use screens.

The first end-use screen was for the interior lighting loads and profiles; the most complicated of the end-uses. The defaults that eQuest used on the sixteenth screen were designed for multifamily applications, such as apartment complexes or hotels. In these types of buildings, there are many residents and dwellings in which lighting use would fluctuate throughout the day. The lighting use in multifamily dwellings would be extremely hard to estimate because each family could potentially have very different schedules. The dwellings in the building would be occupied at differing hours of the day creating a worst-case scenario in which lights would be on in several rooms for the majority of the day. This uncertainty is not as big of an issue in a single-family residential building. A residence may be "occupied" 24 hours a day because people live there, but the lights are not turned on in all rooms during occupancy. Typically, occupants only turn the lights on inside a room when it is occupied, or the lights are needed. And, homes are not often "in use" during the day because people have jobs and are away from the home during the day (approximately 7 A.M. to 6 P.M.). In this particular case, the owner was questioned about the house's occupancy schedule and the lighting use in each room; a luxury that designers of a multifamily buildings would not have. Therefore the interior lighting use for this residence could be pinpointed and analyzed based on what is actually happening. To summarize, the lighting loads in single-family residential buildings are not near as high as multifamily or commercial buildings.

People tend to be innately energy conscious as well. Most are taught from a young age that lights should be turned off when leaving a room to avoid wasting energy and money. When lighting is not necessary, the lighting should be off because people are well aware that using energy is costing money; an issue that homeowners care most about. People seem to also prefer daylighting to artificial lighting in residences and utilize windows during the day when the sunlight is adequate. Interior lighting is most important (or most applicable) when the sun is down or when the occupant is conducting detailed tasks that require particular detail, such as reading or writing. The bottom line is: interior lighting in residences is typically much lower than what would be expected of a commercial building.

The multifamily defaults in eQuest had lighting power densities (LPD's) of 1.1 W/SqFt or 0.8 W/SqFt for example; values that would prove to be very large if multiplied by the area allocation for the residential area type on the first floor. Using the multifamily defaults would lead to a simulation that projects a large amount of energy being used for lighting. In fact, after reviewing the monthly utility bills, the projected lighting use for one month would be close to the total electricity for a month in real life. So, using the commercial defaults was not an option and more accurate LPD's for each area type had to be established.

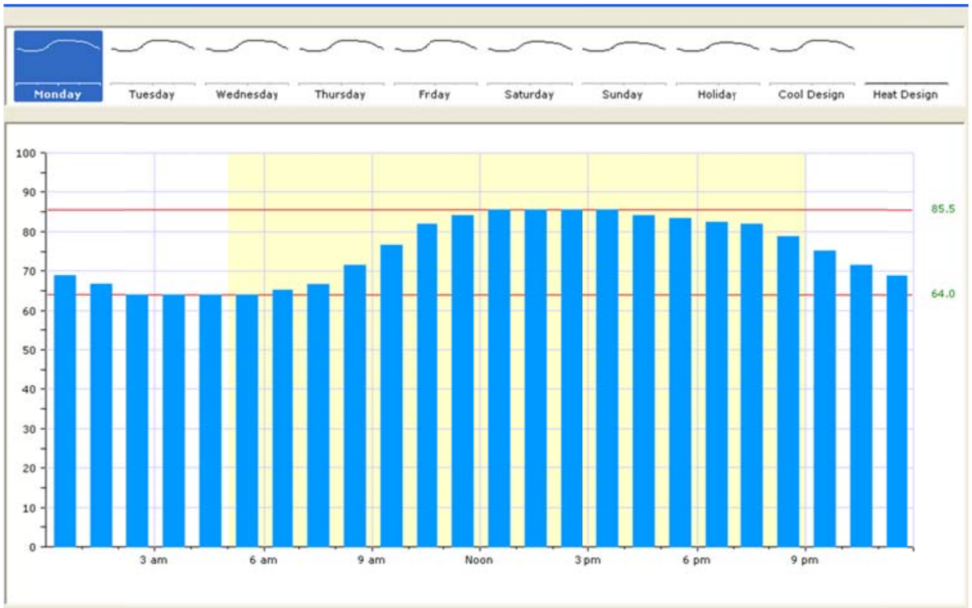
To determine lighting power densities that would prove to be the most accurate, a process had to be developed that would diversify the amount of watts being used from the lighting in a year. The watts being used are seen on the eQuest summary and contribute to the electricity being used each month as reflected on the monthly utility bills. Also, the watts being emitted by a lamp actually increases the heat in that particular room and increases the demand on the cooling load, which is covered through the use of an electrically fueled DX coil.

To be as accurate or realistic as possible, it was decided that the lighting would be estimated based on hourly use. An LPD would have to be established for each area type and calculated based on the hours of lighting used in a single year. To do this, the homeowner had to be questioned about how many hours each week the lights are actually on in each room of the house. Rooms were grouped into the area types discussed earlier: residential, storage, restroom, kitchen, mechanical/electrical room, and corridor. In spaces that rarely see activity or are sparsely used, the total hours of lighting in the year were estimated. The hours of lighting in these types of spaces were found to be very low, however, and the LPD was greatly reduced to almost 1% of the installed wattage in most cases. Rooms that are expected to be occupied most often during the day have much larger LPD's because the wattage level is higher throughout the year. Rooms such as the basement living room, kitchen, den, master bathroom and bedroom are all anticipated to have their lights on 3 or 4 hours a day. This would give these rooms the highest LPD's and therefore the highest lighting load. Other rooms, such as the spare bathroom or master closet, had their lighting use broken down to the quarter or half hour to be more precise.

Once the hours were estimated, they could then be inserted into a spreadsheet for calculating the residential LPD. The hours per day a light was on was then quickly converted into the hours per year and provided the diversification factor. The anticipated hours in a year were divided by the total number of hours in a year (8,765.81) to get the percentage of time a light was actually on in an average year. Most of these percentages were very small, around 1 – 2%, and the more heavily used areas had percentages around 12 – 16%. The installed wattage per square foot was then multiplied by these demand factors to reduce the LPD to a reasonable level that could be inserted into the eQuest model for its respective area type. The spreadsheet used for the LPD reduction calculation can be found in Appendix B. Once inputted in eQuest, the reduced watt per square foot factors were then evenly distributed throughout the building's shells using the area allocations determined earlier.

Now, because the lights were diversified from full strength and assumed to be on at all hours during a year, the hourly profile was adjusted to show that the lights were fully on all of the time. To do this, a refrigeration profile was used (EL2 S-C Refrig Profile) and it can be seen in Figure 3-3. This accounted for the lighting's reduction from its installed power to its less-used, diversified state. Once the annual lighting wattages were fully diversified to a more accurate level, the next end-use to be included in the model was the office equipment.

Figure 3-3 Interior Lighting Hourly Profile



The only office equipment accounted for in any of the shells was the computer. There is a printer, but it is scarcely used, so the owner preferred that it wasn't accounted for in the model. The computer's wattage was diversified in the ASHRAE Fundamentals Handbook and reduced to 130 watts. The 130 watts then had to be converted into a W/SqFt factor. This factor was calculated to be 0.11 after dividing the wattage by the area allocated to the residential type; the area type that houses the computer. An hourly profile that came close to that of the computer use was for the office. After talking with the owner, it was discovered that the computer remained on at all times, but did go into a sleep state when idle. Assuming that the computer was on at all times was a large reason for diversifying the listed wattage and therefore lowered the heat gain to a more reasonable value.

The eighteenth screen in the model was for inputting the cooking loads and profiles. All kitchen equipment contributing to the cooling load was included on this screen, except for the refrigerator. No cooking equipment was located in the basement or garage, so this screen only applied to the first floor shell. The BTUh sensible radiant heat gain for the range top and dishwasher were found in the ASHRAE Fundamentals HVAC book and converted into watts per square foot. Like the office equipment, a W/SqFt factor was inserted into the model to be multiplied by the area allocation and fully account for the sensible heat gain in the kitchen. The total sensible heat gain from kitchen equipment in the space is 2,200 BTUh and converted to 2.9 W/SqFt. Conveniently, an hourly profile for cooking equipment was available that modeled the equipment being used during meal times only, which was considered to be realistic. But, the stove and microwave aren't used for every meal and the dishwasher only runs one or two times a week, so the wattage had to be diversified accordingly. After adjustments, the factor was reduced to 2.5 W/Sq/Ft. This only affected the annual utility bills by about $20 though.

Using a similar process, the heat gain from the refrigerator was calculated on the next screen. The sensible radiant and convective heat gain totaled 1,200 BTUh according to the ASHRAE Fundamentals handbook. The BTUh was then converted to watts and then divided by the area of the kitchen to get a W/SqFt factor. This factor (1.56) was also inserted into the model and multiplied by the area allocation for the kitchen to account for the heat gain. The hourly profile selected for this screen was the refrigeration profile discussed earlier, only more applicable for this type of heat end-use.

The twentieth screen was possibly the most important for calculating the electrical loads for the building. Just like the infiltration rate, the miscellaneous loads were treated as the electrical variable and calibrated to approximate the utility bills. The miscellaneous electrical defaults for eQuest are high numbers that were prepared using the multifamily building type. A multifamily building, such as an apartment complex, would use more electrical plug-loads than a residence because there are many people and many dwellings in the building. With multiple families in a large building, the number of appliances requiring power would increase exponentially. In a residence, however, there is only 1 family, and a few people living in the building. A single family would use very few appliances in comparison. In the case of this project, there are only two occupants and, therefore, not very many miscellaneous loads contributing to the electricity bill.

Another reason for reducing the miscellaneous loads is the fact that ventilation fans are included in the simulation. No ventilation is implemented in this residence, so no fans should be dedicated to supplying outside air. But, the software is updated to reflect the 2004 codes that require ventilation in all buildings, so the ventilation fans cannot be removed. Reducing the miscellaneous loads would balance out the summary reports as far as electrical usage is concerned and the total electrical use what matters most in this research. The ventilation fan use is thought of as a balancing factor that "covers" the miscellaneous loads and other factors that will be discussed later on. These situations, and the fact that all other electrical end-uses are known, made it justifiable to treat the miscellaneous load factors as adjustable variables.

The miscellaneous load factors were reduced slightly using general knowledge of the area and common sense. The factors were lowered until the electrical use was reasonable and approached what was used according to the actual utility bills, which did not take much. The first floor shell had the highest miscellaneous load variables because it is used more frequently than the other two and the only area type adjusted was the kitchen. The kitchen miscellaneous loads were reduced because most were accounted for in the cooking loads and profiles. The only room used on a regular basis in the basement is the living room, and it does not have any major loads being used in it. Therefore, the electrical use in the basement will be lower than the first floor. The residential, mech/elec room, and laundry area types were all lowered slightly because of the infrequent and lower use compared to a commercial building with similar spaces. The miscellaneous load factor for the garage was reduced to 0 because the appliances are not used often enough to affect the average annual utility bills. The exact miscellaneous load factors for the first floor and basement can be viewed in Figure 3-4 and Figure 3-5.

Figure 3-4 First Floor Miscellaneous Loads and Profiles

Miscellaneous Loads and Profiles

		------ Electric ------		---- Natural Gas ----	
Area Type	Percent Area (%)	Load (W/SqFt)	Sensible Ht (frac)	Load (Btuh/SF)	Sensible Ht (frac)
1: Residential (Single Family)	64.6	0.30	1.00	0.00	1.00
2: Storage (Conditioned)	3.9	0.00	1.00	0.00	1.00
3: Restrooms	6.7	0.10	1.00	0.00	1.00
4: Kitchen and Food Preparation	12.4	0.10	1.00	0.00	1.00
5: Corridor	12.4	0.00	1.00	0.00	1.00

Figure 3-5 Basement Miscellaneous Loads and Profiles

Miscellaneous Loads and Profiles

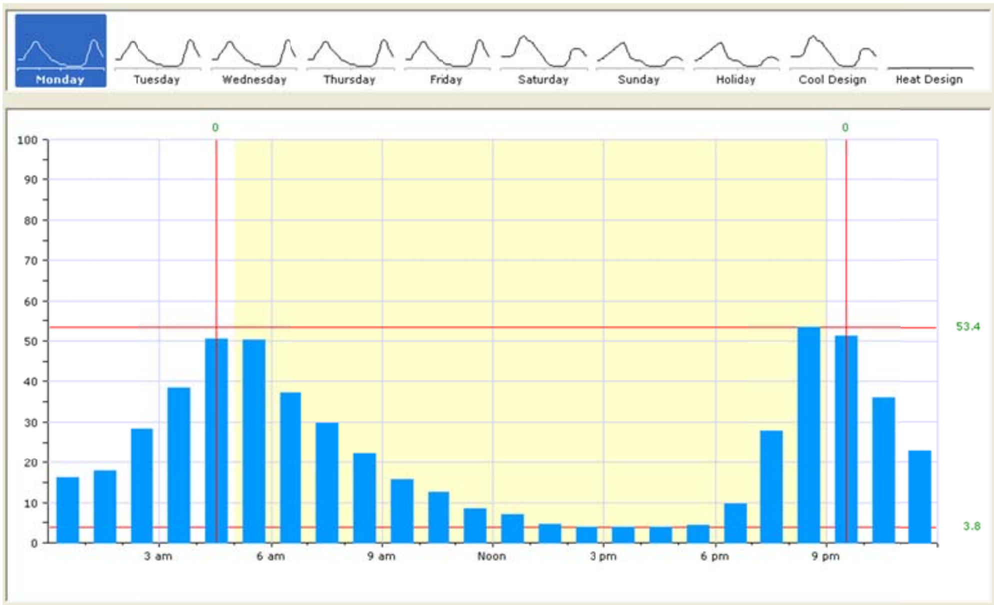
		------ Electric ------		---- Natural Gas ----	
Area Type	Percent Area (%)	Load (W/SqFt)	Sensible Ht (frac)	Load (Btuh/SF)	Sensible Ht (frac)
1: Residential (Single Family)	66.2	0.22	1.00	0.00	1.00
2: Storage (Conditioned)	1.8	0.00	1.00	0.00	1.00
3: Laundry	13.8	0.08	1.00	0.00	1.00
4: Restrooms	3.2	0.10	1.00	0.00	1.00
5: Mechanical/Electrical Room	15.0	0.07	1.00	0.00	1.00

These factors were adjusted based on the electrical activity expected in the space. The residential spaces will experience the largest miscellaneous loads, but, because it is a residential building, the factors will be much lower than the multifamily defaults. Again, multifamily building applications will experience large electrical load end-uses at all hours; much more than a single family residence. Also, the occupants of this particular household do not use many appliances therefore the plug-loads, and miscellaneous loads, will be small. And, no miscellaneous loads are expected in the closets or storage areas, so their respective factors were reduced to zero. The sensible heat fraction remains 1.00 because any necessary adjustments that are required for the load factor are already accounted for in the calculation. The natural gas cells are left blank because no natural gas fuel is used for the miscellaneous loads.

The garage shell originally had a miscellaneous load factor applied to its area, but it proved to be difficult to manage. Because of the large area of the garage, the watts per square foot factor entered would create a larger electrical load than necessary. The calculated watts per square foot for some known appliances proved to be too little to even show up in the model because the smallest number that could be entered is 0.01. The calculated numbers were much smaller and therefore rendered negligible. The owner admitted that the appliances in the garage were not used often and even kept unplugged most of the time because of the seldom use. So, no miscellaneous loads were accounted for in the garage shell. Using the miscellaneous loads as variable produced a projected utility cost that matched the exact utility bill in real life, creating an extremely accurate baseline.

The last screen of the shell editor was for the domestic water heating profile. The profile selected for the water use in this building (for all shells) was the interior lighting profile shown in Figure 3-6. This was chosen because it came close to the actual water use in the home according to the owner. Like in the case of lighting, heavy water use for showers occurs in the early morning or at night. The profile also accounts for small amounts of hot water heating throughout the day, for hand washing or cooking for example. With all of the electrical end-uses now accounted for in the model, the last step was to input all remaining information for the domestic hot water heating equipment.

Figure 3-6 Domestic Water Heating Profile (Interior Lighting Profile Option)



The first screen of the domestic hot water equipment was devoted to non-residential applications and for this building, no such applications were required. So, zero water use was accounted for in this part of the model. The second screen was actually applicable for the water heating equipment because it was for residential buildings. The storage-type water heater in the residence is fueled by natural gas and has a storage capacity of 40 gallons. The nameplate listed the input rating as 40.0 kBTUh and the energy factor of 0.55, and the insulation has an R-value of 12. The water temperature was assumed to be 110°F, heated from the inlet temperature which was set to "equal the ground temperature." No recirculation occurs for this system and therefore was not accounted for in the model.

The "gallons per person per day" was a number derived from analyzing the utility bills. All other data about the water heating equipment was known and inputted into the model, but the gallons of water used in a day is something that changes and would be hard to model accurately. So, to arrive at a reasonable number, the summer heating bills were analyzed and the only natural gas use during the summer would be devoted to domestic hot water heating. Therefore, about 6.5 therms were used during the cooling season. This energy was used for the water heating every month with a slight increase in the winter due to the colder ground temperature. Using this data, the model was adjusted until the "gallons per person per day" value inputted resulted in a natural gas use that matched the actual summer heating shown on the utility bills. Using the water use as a variable was the best way to get an accurate and reasonable value for the domestic hot water heating.

With the shells and domestic hot water heating defined, it was time to create the air-side system for the building. The first screen of the system editor was for defining the system. The system was named "HVAC System" because it is the only one installed. A furnace was inputted as the heating source and DX coils were inputted as the cooling source of the split-system. Because the residence consists of only 1 zone, the system was specified as system per site. The last information that had to be defined was the return air path, which is ducted. Other information was shown on the page but not editable. The thermal zone system assignment at the bottom of the screen shows what shells are assigned to the current system. In this case, the first floor shell and basement shell are assigned to the HVAC System.

The second screen of the system editor was devoted to the interior temperatures and airflows. Seasonal thermostatic setpoints were inputted for the occupied and unoccupied heating and cooling seasons. There was no difference between the occupied and unoccupied cooling setpoints because the residence is occupied 24 hours a day, in theory, and because the thermostat was not adjusted every time the house was left. During the cooling season, the thermostat was set at 75°F and, during the heating season, the thermostat was set at 74°F when occupied and 68°F when unoccupied. The heating setpoint was lowered when unoccupied to balance out the higher heating setting. The heating setpoint is high because the occupants prefer a warmer interior condition than a typical residence, so the unoccupied setpoint was lowered in an attempt to balance out this condition for the utility bills. The indoor design temperatures were inputted the same as the occupied setpoints; 75°F for cooling and 74°F for heating. The cooling design supply temperature was assumed to be 55°F and entered into the model while the heating supply temperature was assumed to be 110°F. And, being a residence, no minimum design air flow rate was entered into the model, and the VAV minimum flow defaults were kept.

The packaged HVAC equipment details were inputted on the third screen. The unit installed in the residence is a 3-ton unit, and it was sized based on the cooling load. How this unit was sized, in theory and in real life, was discussed near the end of Chapter 2 for reference. Based on this size of 3 tons, the unit size was inputted as "< 65 kBTUh or 5.4 tons" into the model. And, because the cooling is direct expansion, an air-cooled condensing unit was required and placed in the system. The SEER rating of the unit is 13 and this was inputted into the model as well. No crankcase heating was allowed.

As for heating, the input size of the heater was entered into the model as it appeared on the unit's nameplate (75.0 kBTUh). Subsequently, the typical unit size was selected to be "< 225 kBTUh" in the next data box. The owner knew the efficiency of the unit and an AFUE value of 0.94 was inputted into the appropriate data field as well.

The fourth screen of the system editor was concerned with the HVAC system fans. The motor efficiency of the fan was assumed to be 1.00 inches W.G. at standard power. The fan flow was chosen to be auto-sized, but the outside supply air information caused some problems. Because no outside air is accounted for in the actual system, it was desired that the eQuest program be modeled the same way. Unfortunately, no such outcome could be reached, and ventilation had to be accounted for. Because of this, the ratio of flow was left at 1.15 because it kept the ventilation fan use the lowest. The minimum outside air sizing method was set by critical zone and the minimum outside air control method was by fraction of hourly flow also. The exact fan type used in the residence's system was not an available option, so a forward curved centrifugal fan with inlet vanes was selected.

Information about the system was edited further on the fifth screen. Here, details about the fan schedule were inputted. The fan schedule was inserted into eQuest with the same details as the building operation schedule analyzed earlier. The fans were set to come on at 5 A.M. and go off at 9 P.M. with no fan operation before or after the "opening" and "closing" of the building; a residence is basically "open" 24-hours. The fan mode 'On' mode was described as continuous because it is fully on and not intermittent or on a delay, and there was no fan night cycling selected for the model. Again, the fans were only on when demand was specified by the thermostat.

The sixth and final screen of the system editor group was very simple. The only data required to be entered into the model was for the HVAC zone heating and economizer information. No baseboard heating was present in this home, so no details had to be inserted into the heating section. Similarly, no economizer system exists on this building, so none was selected. A large part of this is because the system can be shut off at any time and the windows opened to simulate the economizer situation discussed earlier. With the windows opened, the desirable indoor temperature could be reached and maintained because of a light breeze alone.

Or, with the windows open the mild outdoor climate becomes the indoor climate through diffusion. In essence, the system is not needed, or running, because the interior temperature is at a point where no heating or cooling is required due to the mild outdoor conditions. With the baseboard and economizer data completed, or excluded, the system was done being created and assigned to the conditioned shells. But, an unconditioned shell had to be accounted for.

The garage was included in the model because it is a part of the residence for one, but also because it shares a wall with the kitchen. Sharing a wall separates the conditioned kitchen from the unconditioned garage, but it also insulates the kitchen from heat gains or losses that would be experienced if no garage existed. This insulation made creating the garage shell a necessity, and shells have to be assigned to air-side systems in the model. So, using eQuest, a subsequent unconditioned system was created consisting of 1 screen. On this screen, there was little information necessary. The cooling and heating sources were set to zero and no system types were created completing all required data fields. The system assignments could also be checked at the bottom of the screen and verified that the only unconditioned shell was the garage.

With all applicable screens and data boxes filled out, the model was finally created. All shells were accurately constructed, the systems were modeled to what was installed in the residence, and the utility rates and water use was approximated based on the actual utility bills. The house as a whole was created in a way that allowed the energy-use outputs to be summarized and analyzed accurately. The model is not perfect, but it is close considering the constraints of eQuest and the habits of the occupant.

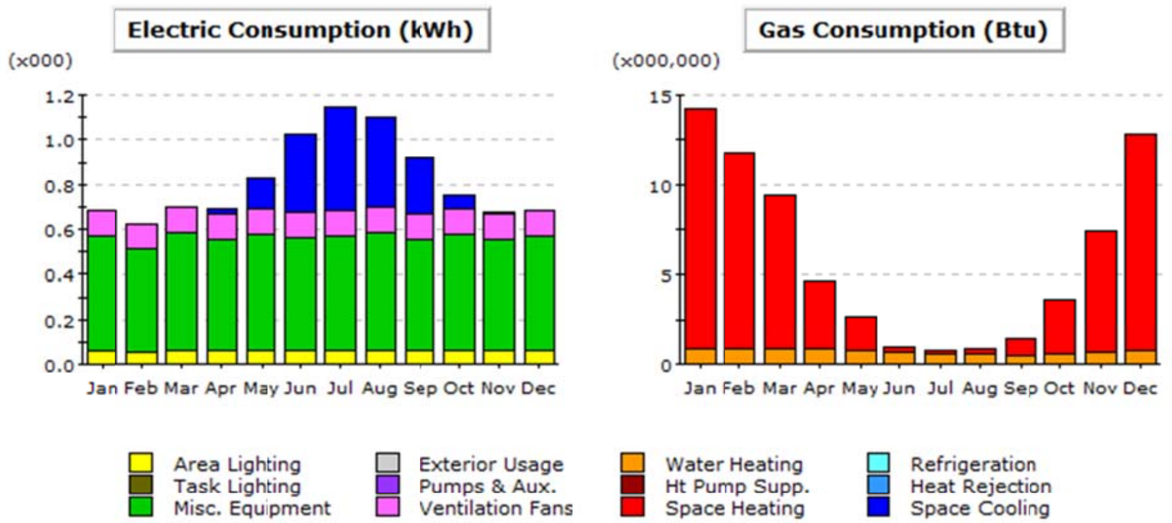
Analyzing the Outputs

The purpose of creating a model of the residence in eQuest was to produce various outputs that could be analyzed for beneficial reference by all homeowners or homebuyers. Running a simulation for this building produced outputs in the form of electricity and gas use by month and year and the cost per month of all utilities used in an average year. These simulation reports helped create a baseline that could be referenced. Enhancements or improvements could then be made to the building envelope and systems, and the subsequent money savings, or typical payback, could be determined and documented from the baseline outputs for review. The goal of this report is to offer homeowners or buyers information about energy use. Is it worth it to upgrade various parts of the construction? This question can only be answered through creation of a summary report and extensive knowledge of what it represents.

To simulate the performance of the building, the appropriate button (Simulate Building Performance) was clicked. To produce the outputs, eQuest calculates the heat balance equation based on several years worth of weather data for each month of the year for a city closest to the construction site. The weather file must be downloaded first before the data can be analyzed. Upon selecting "simulate building performance," a prompt asks that the weather file is downloaded from the DOE2 website before proceeding. After downloading the file, the average climate for each month was considered and the energy required to maintain the desired interior thermal conditions for the building was estimated and calculated for that month and projected as an output. Various summary reports are available for review, and they reflect how the outputted data is affected by the inputs of the model after being cross-examined by the weather data. After all, the outdoor climate is creating the need for the indoor conditioning of buildings. And, with the electric and gas rates inputted into the model, the energy use simulated by the model could be used to produce the monthly utility bills in summary form.

The bills are what matter most in this analysis because saving money is what matters to most homeowners. This is why the model was adjusted and re-adjusted several times to get outputs that were as close as possible to the actual house's energy consumption. When the model was complete, the output summary report produced numbers that were very close to the numbers listed on the homeowner's average monthly utility bills (based on 6 years of data). The kilowatt use per month was close, but the yearly total was what mattered and proved to be closer. The natural gas use was the same, and close to the actual yearly average. The monthly utility bills were projected by eQuest but, again, the most important things were the average yearly costs of the electricity and natural gas. The annual cost of the bills was something that could be referenced clearly after any of the forthcoming adjustments were made. And, the annual electric and gas bill reports can be easily read and compared to other reports by the homeowner. The following reports (Figure 3-7 and Figure 3-8) display the annual utility costs and the annual energy uses, respectively.

Figure 3-7 Monthly Energy Consumption by End-Use



Electric Consumption (kWh x000)

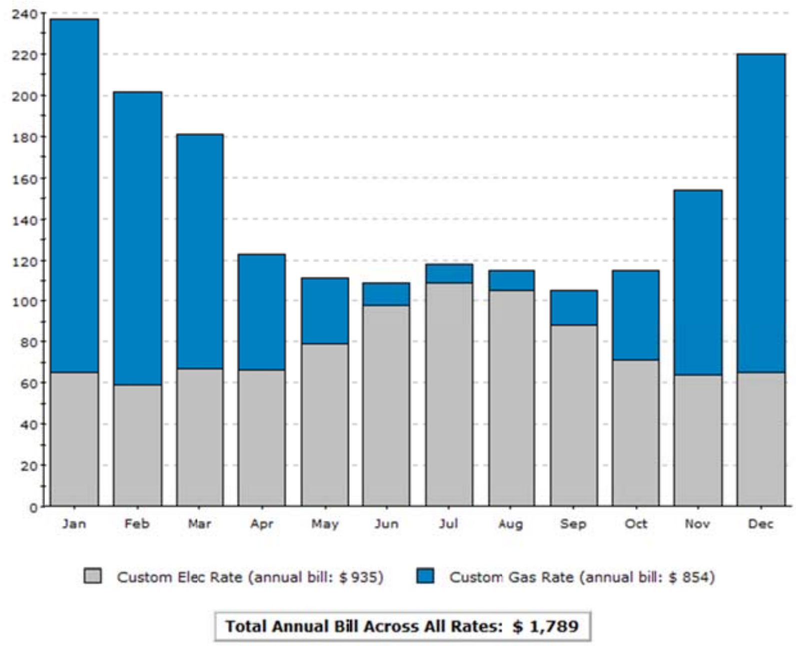
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	0.00	0.00	0.03	0.14	0.35	0.46	0.41	0.26	0.06	0.01	-	1.72
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.11	0.10	0.12	0.11	0.11	0.11	0.11	0.12	0.11	0.11	0.11	0.11	1.34
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	0.51	0.47	0.52	0.50	0.52	0.50	0.51	0.52	0.50	0.51	0.50	0.51	6.07
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.06	0.71
Total	0.68	0.62	0.70	0.69	0.83	1.03	1.15	1.10	0.92	0.75	0.67	0.68	9.84

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	13.36	10.97	8.51	3.87	1.93	0.32	0.16	0.30	0.89	3.06	6.75	12.03	62.16
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.86	0.82	0.89	0.82	0.74	0.62	0.56	0.52	0.51	0.59	0.66	0.79	8.39
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	14.23	11.80	9.40	4.69	2.67	0.94	0.72	0.83	1.41	3.65	7.41	12.83	70.55

The electric and gas consumption are both displayed in color-coded bar graphs and in statistical tables for precision in the main, or default, summary report. The various end-uses that draw energy from the system (space cooling, space heating, misc. equipment, etc.) are listed in the legend below each graph and each table. The electrical consumption data is represented by the number of kilowatt hours (x 000) consumed by month. The natural gas consumption data is denoted by the number of BTU's (x 000,000) consumed by month as well. The annual consumption of each fuel can be found at the lower right-hand corner of the table and are the numbers that will be referenced and compared between the future, adjusted models.

Figure 3-8 Monthly Utility Bills – All Rates (Electricity and Natural Gas)



The monthly utility bills are also displayed in a color-coded bar graph, but with no supporting table. The annual electric and gas bill costs are listed beneath the graph along with the total annual bill of both bills combined. And, the projected annual costs are either exactly what was calculated for the average utility bills or extremely close. These data groups will prove to be the most important part of the research when it comes time to compare annual money savings from construction adjustments.

In order to compare the model to the actual residence's energy use, the utility bill data had to be compiled and sorted in a spreadsheet. This spreadsheet contains electrical and natural gas consumption dating back to January of 2006. The following table includes the average energy use and monthly utility bill costs for all of the collected data. The entire data set can be viewed in the appendices.

Table 3-1 Average Annual Energy Uses and Costs

	Electric			Gas				
Average	Cost	kW	$/kW	Cost	MCF	BTU	Therm	$/Therm
January	$56.38	644.67	$0.09	$170.51	15.08	15,090,583	150.91	$1.10
February	$54.12	597.17	$0.09	$161.56	13.92	13,492,417	134.92	$1.20
March	$50.24	527.33	$0.10	$100.04	8.35	8,575,450	85.75	$1.17
April	$49.76	500.17	$0.10	$60.21	4.30	4,416,100	44.16	$1.36
May	$53.34	536.00	$0.10	$30.75	1.70	1,745,900	17.46	$1.76
June	$93.85	999.00	$0.09	$19.66	0.63	650,433	6.50	$3.02
July	$130.55	1,261.83	$0.10	$19.46	0.60	616,200	6.16	$3.16
August	$142.32	1,374.50	$0.10	$19.83	0.65	667,550	6.68	$2.97
September	$96.37	1,043.50	$0.09	$19.58	0.63	650,433	6.50	$3.01
October	$84.84	771.83	$0.11	$32.68	1.95	2,002,650	20.03	$1.63
November	$60.91	657.67	$0.09	$66.66	6.10	6,664,700	66.65	$1.00
December	$63.31	725.40	$0.09	$152.05	14.96	14,163,920	141.64	$1.07
Annual Charge=	$935.98		$0.095	$852.97	=Annual Charge			$1.21

Figure 3-9 Monthly Electricity Use Comparison

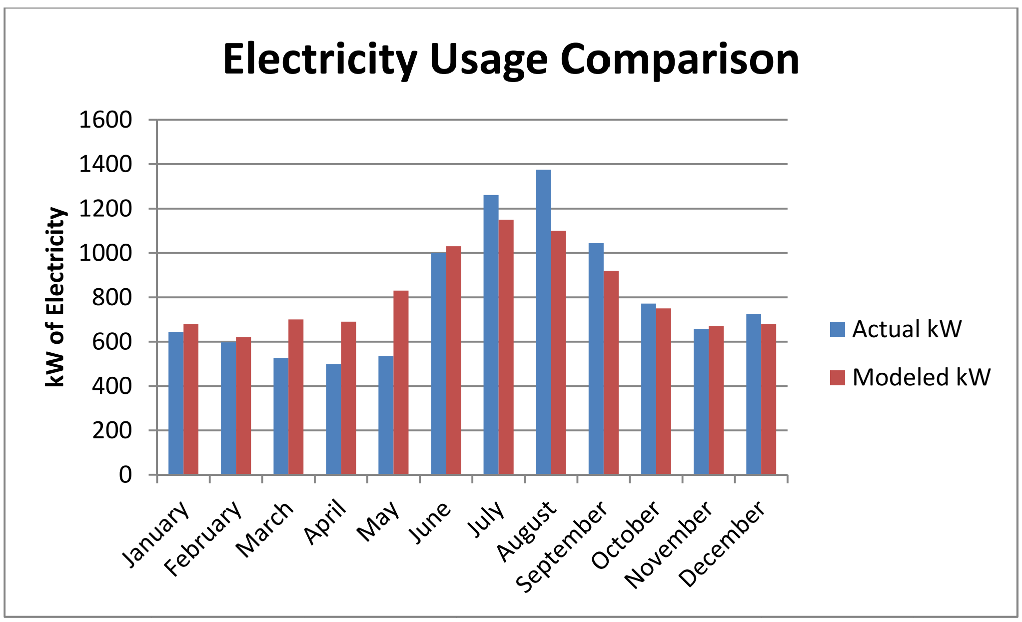
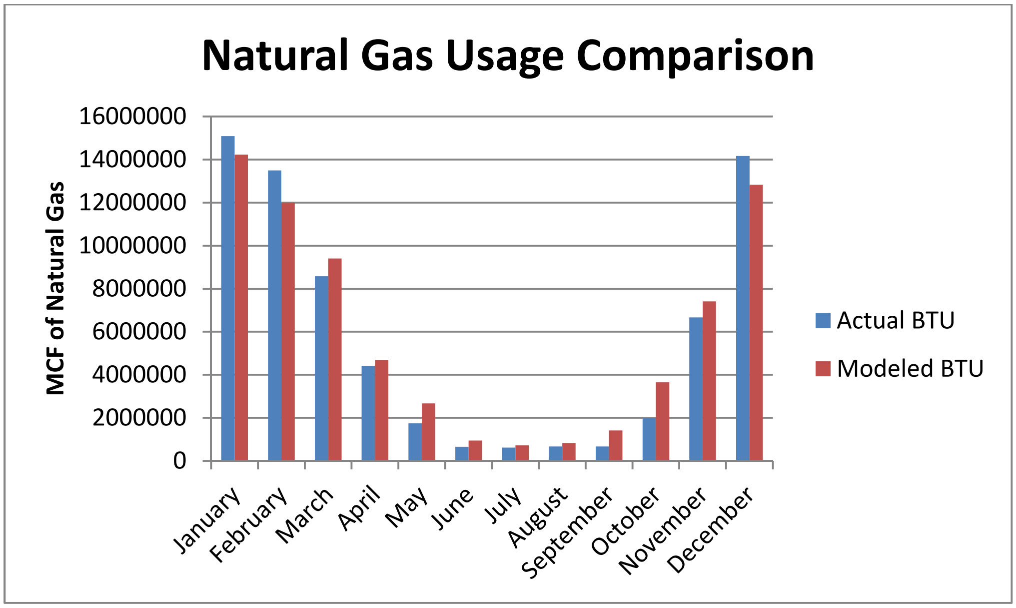


Figure 3-10 Monthly Natural Gas Use Comparison



Comparing the average utility bills to the model, it can be seen that the model is an accurate representation of the actual energy. The average, annual electric charges totaled $935 and that is exactly what the eQuest model estimates. The average, annual natural gas charges totaled close to $853, $1 less than what the model projected ($854). The monthly energy use profiles are very close for both graphs, but the summer electricity use appears to separate. This could be explained by flexible thermostatic setpoints. Because the trend is close in all other months, it would appear that the occupants just turn the thermostat down during the hottest months. Though the actual energy use in the summer is higher than the modeled, this would support potential envelope improvements. Limiting the heat gain in the summer through the installation of more insulation would yield higher energy savings in the model. Having a model this accurate was crucial for analyzing the changes made for the benefit of the homeowner. Each of the improvements documented in the following pages would lower the cost of energy used in the residence and provide homeowners with pertinent information relating to energy conservation. Figure 3-9 and Figure 3-10 show a comparison of the monthly energy usages as well.

The model is not perfect, unfortunately. A few problems with the eQuest program led to some deviations from the actual energy use compared to the summary report. The problems are not serious and can be explained. Each of these issues will be discussed and justified in the next section.

Problems with the Model

The first problem with the model has been discussed frequently: the fact that the eQuest model accounts for ventilation in the home. The residence was built in 1970 and, at that time, no ventilation was required by code. So, no outside air was brought into the home nor were ventilation fans included in the HVAC system. But, because the most updated version of eQuest was used (2010), the model incorporates the 2004 version of ASHRAE 90.1 and accounts for a minimum ventilation rate in all building types; the most current version of ASHRAE 90.2 sets a minimum ventilation of 50 CFM for residence's built tightly.

EQuest has multiple options available within the program for manipulating the ventilation rates used for commercial buildings, but no such options exist for residential buildings. And, because this building was built in 1970, an option to neglect all ventilation was definitely not possible. The area allocation screen has data boxes for entering the minimum ventilation rate per square foot and zeroes were entered into every one for all shells. In the system editor, the fan schedules were also thought to be adjusted so that no outside air was included in the cycling. Furthermore, the HVAC system fan screen of the system editor had a section for outside supply air as well. The outside air flow was specified to be 0 CFM and the minimum sizing method for the outside air was set to be the "sum of zone OA (default)." The minimum control method for the outside air was set to be "fraction of design flow (default)." Even after adjusting the outside airflow rate to 0, however, ventilation fans still showed up in the electrical summary report. The ventilation fan use was not insignificant; the simulation projected power consumption devoted to running the fans and consequently greatly affecting the energy usage and utility bills. Therefore, the ventilation fans could not be ignored entirely.

As a result of the ventilation fan inclusion, the subsequent wattages being devoted to them were used as a sort of "gimme" factor, or cushion, for the electrical use. It has been well-documented about how the miscellaneous electrical loads were diversified and treated as a type of variable for the monthly wattages, so ventilation fan usage could be treated as a correction, or balancing, factor for the reduction. The miscellaneous loads were reduced because they could be, while the ventilation fans could not. The miscellaneous loads did not require significant adjustments, just enough to create a strong baseline. If no fans were mandatory, the miscellaneous load defaults could have been left alone and adjusted accordingly to match the actual utility bills. But, the model is not perfect, and the total watts ultimately had to be accurately projected. To do this, the miscellaneous loads were reduced greatly and the ventilation fans reduced as much as possible while still showing up in the energy use summary report. In essence, the ventilation fans "covered" for the miscellaneous load reduction and for other problems in the model.

Though the miscellaneous loads were reduced, the presence of the ventilation fans could also be used to balance another issue. Thermostat availability and the fluctuation of its setpoints are major issues within residential buildings. With a thermostat that can be changed on a whim, any model created to simulate the building's energy use would be difficult to approximate. Occupants can lower the thermostatic setpoint whenever they feel slightly warm in summer, and they can keep it lowered as long as possible. Since humans are not machines, they can forget that the thermostat was lowered. This can leave the system running at a more arduous state to overcome the larger temperature difference and lead to a higher energy use. Including the ventilation fans—though it is not a choice— is a way of accounting for these scenarios. With the "additional" fan use appearing in the summary report, it is really just a mislabeled load "cushion" that slightly accounts for the thermostat fluctuation and the diversified miscellaneous loads. Instead of ignoring the ventilation fans because they do not exist in this residence, they serve a purpose and try to balance the model's energy use. And, to avoid altering the spreadsheet, it is simply asked of the reader that the "vent. fans" electrical end-uses appearing in the summary report be thought of as "attenuation" loads that approximate the energy use as close as possible to the actual utility bills.

For problems with the construction of the model, the wall heights were not inputted exactly correct. As was mentioned earlier, the basement walls are 8 feet high with 2 feet above grade that includes a few windows. This cannot be accurately represented in the model because no windows can be placed in the below-grade shell. So, the basement shell has wall heights of 8 feet, but the windows are included in the first floor shell that had its wall height increased by 2 feet. The windows had to be represented in the model on the right orientation of the residence; the fact that they were placed a little higher than they are in reality does not affect the heating calculation greatly, if at all. The fact that the first floor shell had its wall height increased 2 feet is not ideal, but it can be explained by the wall area that had to be attributed to the attic space above the first floor ceiling. The pitch of the roof could be inputted into the model and footprint customized to an extent, but the exact location of the actual hip and gable construction could not be replicated in the mode. So, extra wall area was necessary to account for the lack of precision. The interstitial space for the floor construction between the basement and first floor shells also had to be accounted for in the model. This area, though much smaller than the missing attic area, had to be present to balance out some of the missing wall space too. In conclusion, adjusting the wall heights in the model had to be done to include the windows, but the adjustment could be justified. And, windows tend to matter more than wall area in terms of heat transfer anyway, so their correct placement took precedence over exact wall replication.

For some reason, the overhang of the roof cannot be replicated in this eQuest model. The residence has an eave that extends as far out as 3 feet on some sides of the house, greatly affecting the shading of the windows. There is also a covered deck off of the northeast corner of the house that covers most of the sunroom's east-facing windows. But the other windows of the house are exposed, or treated as such for a worst-case scenario.

Not being able to input this exact construction into the model was initially of concern. But, when considering that the model would be used to explore improvement options on future houses, the lack of a covered deck is not as problematic. Many houses built in the near future would have a similar envelope construction, but not sunrooms with little to no direct sun exposure. Therefore, the lack of such a shade was dealt with in another way. The north window in the kitchen is completely shaded at all times of the day due to its orientation and because of how the overhangs "overlap" in that particular section of the roof. These omissions led to the adjustment of the shading coefficient. The default for the coefficient was 0.843, a fairly large value considering that the ACCA Manual suggests that the values fall between 0.20 and 0.70. So, after discussing this issue with the owner, the shading coefficient was reduced to 0.35 to account for the missing overhang, internal blinds (that are accounted for in the model, but only a percentage of the time), and even the shading that occurs due to the presence of trees on the east side of the property. Other such houses and possible new homes may have factors unaccounted for that would offer shade for the windows and lead to a lower shading coefficient as well.

With the shading coefficient reduced significantly, the space heating for the residence is affected. Decreasing the shading coefficient lowers the solar heat gain through the windows. This is desired during the summer months as the solar heat gain directly affects the cooling demand on the system, but during the winter months, this "free heating" is lost. During the winter, the temperature drops and the sun hangs lower in the southern sky, but it is still shining.

The solar heat that passes through the windows of the residence during the heating season actually aids the furnace and provides the space with a small amount of heat, something previously referred to as “free heating.” If the windows are heavily shaded, however, or the shading coefficient is reduced, the amount of solar radiation is reduced as well, and the system has to work harder to overcome its absence. This explains why the infiltration had to be slightly lowered in the model. With a larger heating demand during the winter months, the infiltration had to be decreased to balance out the system and model what is actually happening in the home in terms of energy use. All of this was done to get a total gas and electricity usage that matched what was actually being used in the residence according to the utility bills. The shading coefficient is not perfect nor is the infiltration rate exact, but the coefficient is within a reasonable range (on the low end) and the infiltration rate is for tight construction, though tighter than originally assumed, but the end result produced an accurate model.

Weather can also cause problems with the model because of its inconsistency. The averages for the last 6 years of utility bill data were taken to try and counteract the inconsistency of the weather and get data that is close to a typical year. But, weather is unpredictable and some months, or even years, can have outliers that skew the data. And, because the bills only date back 6 years, one or two years of atypical weather can cause problems with the average utility bills. The winter of 2012 was a very mild and therefore not a lot of natural gas was used for heating. This one year could tip the scales in favor of lower utility bills compared to a model that calculates its own bills based on a 30-year average. The 30-year average is a much larger sample size and can overcome mild winters and summers to get a more accurate utility bill and simulate typical energy uses. To test whether or not the available utility bills were a hindrance or not, the past 6 years of weather had to be compared to the past 30 years, or close to it.

Weather data was available through the Kansas State University website. The average monthly high temperatures dating back to 1985 were compared to the data for the past 6 years. The average high temperatures for each month dating back to 1985 can be seen in Table 3-2. The standard deviation, average high temperatures for each month dating back 6 years, and the degree difference can also be found in the table. The table shows that the 6-year average is close to the averages of the 26-year data set, but it is just an average high temperature. The temperature trends are not known and outliers can affect the data again. But, it appears that the 6 years worth of utility bills provides enough data to create an accurate model.

Table 3-2 Weather Data

Month	Average Max Temp. (°F)	Standard Deviation (°F)	6 Year Average	Difference
January	40.3	6.0	40.2	0.1
February	45.0	6.3	43.1	1.9
March	56.7	4.1	56.8	0.1
April	67.3	3.6	67.7	0.4
May	76.5	3.3	75.8	0.7
June	85.5	3.4	86.5	1.0
July	90.5	2.8	90.6	0.1
August	89.2	3.6	90.4	1.2
September	80.6	3.4	79.4	1.2
October	69.0	3.7	69.0	0.0
November	54.2	5.6	56.3	2.1
December	42.4	5.3	41.7	0.8

The model was not flawless and problems were expected. The purpose of this model was to simulate energy use that was as close as possible to the energy use of the actual residence, not create a perfect building. This task was made easier when the problems were overcome and balanced by using some of the inputs as variables to get accurate summary reports and utility bills. Adjusting the miscellaneous loads and the infiltration rate was not ideal, but it had to be done to get end reports that could be analyzed and provide utility bills that create an accurate baseline. Once all of the problems were manageable and justifiable, the model could be treated as a baseline for various improvements upon the residence. The building construction was enhanced and the resulting energy savings were documented. Owners could then be provided with reference material for making home improvements to save money in the long-run. The various enhancements and improvements will be discussed in the following chapter.

Chapter 4 - Results

The purpose of this research is to provide homeowners and homebuyers with tangible data about saving money through envelope and system improvement. Improvements made to the building's envelope would lower the energy used by the HVAC system. Enhancing the construction of the building would prevent heat gains or losses through the envelope that prove to increase the demand on the system. Tightening the construction, improving the glass of the windows, or increasing the insulation in the walls are all scenarios in which energy would be conserved and the utility bill costs reduced. Adjusting the interior thermostatic setpoints was also considered. The model created earlier was changed to reflect building improvements, the results were analyzed, and the annual money savings documented for future record and homeowner reference.

ASHRAE 90.2 Baseline

Some potential improvements could not be made to an existing house, but could only be implemented during construction. To show energy savings for these types of improvements, a baseline had to be created that met the current code. To do this, a baseline model was created using ASHRAE 2007 Standard 90.2: Energy-Efficient Design of Low-Rise Residential Buildings.

The building envelope was created in accordance with the prescriptive envelope criteria of chapter 5 in ASHRAE 90.2. Table 5.2 provided minimum R-values and maximum U-values that were used in the model. Before taking values from the table, however, the climate zone had to be determined. And, according to Table 9.1 Climate Zones – United States, this particular building falls into Zone 4A. With the climate zone known, the envelope criteria could be concluded ("ASHRAE 90.2", 2007).

Using Table 5.2, the minimum cavity insulation for a wooden frame wall system had to be at least R-15 with continuous insulation totaling R-5. This was data was inputted into the model as R-15 batt insulation with a continuous, rigid board insulation of R-5 being accounted for as well. For the below-grade basement walls, no minimum value was set, so the model U-value was left at zero. The minimum cavity insulation for the attic space, or above-ceiling insulation, was found to be R-38. The U-value for any door to the residence could not exceed

0.39, and no window U-value could exceed 0.35. No maximum solar heat gain coefficient was set for a building in climate zone 4.

The system details were inputted into the eQuest model in accordance with chapter 6 of ASHRAE 90.2. Table 6.9, Minimum Requirements for Non-Federally Covered HVAC Equipment, lists requirements for an evaporatively cooled split system unitary AC unit. From the table, it was determined that the minimum EER value for such a system is set at 9.3, which is equivalent to a SEER of approximately 10 ("U.S. DOE Building America House Simulation Protocols" 2010). No combustion efficiency details could be found in ASHRAE 90.2, however. But, the minimum values for combustion efficiency in ASHRAE 90.1 are approximately 80% for all systems and specifically 80% for small furnaces, so that was the number inputted into the ASHRAE Baseline model.

The infiltration rate is another topic that is not discussed in ASHRAE 90.2. In the original model, the infiltration rate was treated as a variable and the default value was improved upon to get a rate of 0.36 ACH to match the heating utility bill with the simulation. But, in this case, no base point was offered, so the ASHRAE Principles of HVAC handbook was used. Table 5-1 offers typical infiltration rates for buildings with varying degrees of construction tightness (depending on the heating temperature difference). For the baseline and its purpose, the building was considered to be tight and the infiltration rate was set at 0.51 ACH; looser than the original model. This was done to account for homes that are built to the minimum rate to achieve a "tight" standing; though improving the tightness further would save money.

The domestic hot water details were calculated using equations provided in Section 8.9 of ASHRAE 90.2. The "average gallons per day of hot water consumption" was determined to be 8.445 using equation 8-11. This equation accounts for a clothes washer being present in the home and includes a "13.2 gallons per day per person" factor.

No other changes were made to the original model. The lighting use was kept the same because a typical residential home would see similar lighting power densities. Most occupants keep lights off in unoccupied rooms and utilize daylighting, so it was assumed that the impact of the annual lighting on the utility bill would be minimal. The occupant electricity consumption was addressed in ASHRAE 90.2, but the calculated value was not a number that could be used effectively in the model.

With a an ASHRAE 90.2 Baseline, documented envelope and system improvements could be provided to builders of new homes that have to comply with the current codes. Changes and enhancements could be made to the baseline model to show what happens when the home is built a little better, or the owner goes the “extra mile” to save on annual energy use. The purpose of this model is to provide home builders with information that will allow them to make decisions when it is time to go with the standard or pay a little more for lower utility bills and a shorter payback.

The minimum ventilation required in the residence was not changed for the baseline model. The minimum rate set by ASHRAE 90.2 is 50 CFM and a calculation found in a report titled “Building Codes and Indoor Air Quality” set the minimum at about 60 CFM. These small rates will not overcome the ventilation fan usage that the model already accounts for (and cannot be removed). So, the ventilation was not changed and was still balanced by attenuating the miscellaneous loads. The annual bill may even be a little less than what was projected, but it was not considered a significant influence and therefore omitted.

Building Envelope Improvements

The first improvements explored in the model were concerned with the building envelope and, more specifically, the insulation efficiency. Because the cost of improving a building’s above grade insulation would be astronomical, this analysis was considered for new construction opportunities only and technically not considered an “improvement” for an existing home. The cost of tearing out the interior gypsum board to add more insulation would take a lot of labor and prove to be much more costly than the potential energy savings. So, this part of the analysis was done for the benefit of those building a home and considering all insulation options. Would it be worth it to improve the insulation of an above grade frame wall? This question is one that will be addressed.

The above-grade construction of the current residence consisted of 2” x 4” frame walls with R-15 batt insulation and considered the baseline for all future improvements. This was done for two reasons: a model was already created and available for analysis, and many homes built in the same time frame were constructed in a similar way. Though this residence was built tighter than most during that era, it would still prove to be a solid reference point for improving a residential building’s envelope. Because new homes would have to be built up to the current standards, the ASHRAE 90.2 baseline created earlier was also used as the model improved upon.

Keeping everything else constant for the existing envelope construction, the thermal resistance (R-value) of the envelope was increased by adding rigid foam insulation to the original batt. Owens Corning FOAMULAR 150 rigid board was the type of insulation considered for the model and the available R-values are R-5, R-7.5, R-10, and R-15. This type of insulation is available at a local Menards at listed prices typical of the area.

The original wall with 2” x 4” studs at 16 inches on-center with R-15 batt was used as the base. The insulation was increased and the improvements were reflected in the annual utility bill savings. The following simple payback and return on investment formulas in Equation 4-1 were used to determine if the improvements were necessary or worth considering:

Equation 4-1 Payback Period and Return-On-Investment

$$\text{Payback Period} = \frac{\text{Improvement Cost - Initial Investment}}{\text{Annual Money Savings}}$$

$$\text{Return-On-Investment} = \frac{\text{Annual Money Savings}}{\text{Improvement Cost - Initial Investment}}$$

The costs of the installation of the frame wall and insulation were also considered in order to get accurate paybacks and returns. For the frame wall, a 12 foot section of wall was evaluated. In a 12 foot section of wall, there is one 12 foot plate on the bottom of the frame, two plates on top and (9) 8-foot high studs in between (at 16 inches on-center). The cost of batt insulation in a 3.5 inch cavity is $0.42 per square foot according to The Home Depot and $0.61 per square foot in a 5.5 inch cavity (2” x 6” studs). For a 12 foot section of wall with 2” x 4” studs, the cost of the lumber is roughly $39.78 and multiplied by the number of 12 foot sections expected in this building (18) to get an estimated cost of the frame to be $716. This cost was arrived at using the Menards website. The cost of a 12’, 2” x 4” plate (#2 & better lumber) is $4.65 if the discount is not included and the cost of an 8’ stud (#2 & better) is $2.87. The cost of the insulation is $595, found by multiplying the cost of insulation by the 1368 square feet of above-grade wall. All pricing data can be found in Appendix D.

For a 2” x 6” wall, the cost of the framing was calculated the same way but found to be $1,115 and the cost of insulation for a 5.5 inch cavity was increased to $834. These total costs were considered the base costs and the subsequent cost of the rigid board insulation was added as each scenario was analyzed.

The first scenario explored included adding ¾ inch fiber board sheathing to a 2” x 4” stud wall with only R-15 batt insulation and can be seen in Figure 4-1. If the wall only had the batt insulation, it would not be up to code because R-5 continuous insulation is required thus the R-5 fiber board sheathing. This option actually produced the quickest payback period (11.95 years) because it is not very expensive and the added thermal resistance made a difference. After the sheathing option was considered, adding varying thicknesses of rigid polystyrene board insulation to 2” x 4” stud walls was documented. Each option was evaluated from R-5 to R-15 and the annual savings, payback period, and return-on-investment were considered, and each time, they increased. The same process was evaluated for 2” x 6” walls with R-15 and R-21 batt insulation and then again using the ASHRAE 90.2 baseline model (indicated by the shaded cells) to show improvements upon a residence being built up to the latest code. Whether or not to build a residence using a 2” x 4” stud wall or a 2” x 6” stud wall is a serious question in the construction industry. Building a residence with a 2” x 6” stud wall, R-15 batt, R-5 continuous insulation, and the same R-42 above-ceiling insulation inputted in the model only saves $56 annually. The payback period for this construction is 24.38 years, not reasonable. Installing a 2” x 6” frame wall with R-21 batt and R-5 continuous insulation would save a little more money annually, but only decrease the payback period to 18.94 years. So, increasing the thickness of the stud walls would allow more batt insulation in the wall cavity, but it would not significantly save money in the long-run. This data shows that only installing a 2” x 6” wall with no other improvements would not be worth it financially. The entire dataset can be viewed in Figure 4-1.

Table 4-1 Above-Grade Wall Improvements and the Annual Savings

Enevelope Construction	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Utility Bill	Energy Bill	Insulation Cost	Framing	Initial Cost	Cost Difference	Payback	ROI
Original Above-Grade Wall Insulation, 2 x 4 studs, 16 in. o.c., R-15 batt	15.0	0.0	42.0	$1,789	-	$575	$716	$1,291	-	-	-
2 x 4 studs, R-15 batt, R-5 3/4 in. fiber board sheathing	20.0	0.0	42.0	$1,737	$52	$1,196	$716	$1,912	$621	11.95	0.08
2 x 4 studs, R-15 batt, R-5 1 in. polystyrene	20.0	0.0	42.0	$1,735	$54	$1,281	$716	$1,997	$706	13.08	0.08
2 x 4 studs, R-15 batt, R-7.5 1.5 in. polystyrene	22.5	0.0	42.0	$1,729	$60	$1,539	$716	$2,256	$964	16.07	0.06
2 x 4 studs, R-15 batt, R-10 2 in. polystyrene	25.0	0.0	42.0	$1,716	$73	$1,860	$716	$2,576	$1,285	17.61	0.06
2 x 4 studs, R-15 batt, R-15 3 in. polystyrene	30.0	0.0	42.0	$1,685	$104	$2,464	$716	$3,180	$1,889	18.16	0.06
2 x 6 Studs, R-19 Batt	19.0	0.0	42.0	$1,760	$29	$625	$1,115	$1,740	$449	15.48	0.06
2 x 6 Studs, R-21 Batt	21.0	0.0	42.0	$1,744	$45	$834	$1,115	$1,950	$659	14.63	0.07
2 x 6 Studs, R-15 Batt, 1 in. polystyrene, R-5	20.0	0.0	42.0	$1,733	$56	$1,541	$1,115	$2,657	$1,365	24.38	0.04
2 x 6 Studs, R-21 Batt, 1 in. polystyrene, R-5	26.0	0.0	42.0	$1,705	$84	$1,464	$1,115	$2,579	$1,288	15.33	0.07
2 x 6 Studs, R-21 Batt, 1.5 in. polystyrene, R-7.5	28.5	0.0	42.0	$1,701	$88	$1,799	$1,115	$2,915	$1,623	18.45	0.05
2 x 6 Studs, R-21 Batt, 2 in. polystyrene, R-10	31.0	0.0	42.0	$1,686	$103	$2,120	$1,115	$3,235	$1,944	18.88	0.05
2 x 6 Studs, R-21 Batt, 3 in. polystyrene, R-15	36.0	0.0	42.0	$1,671	$118	$2,981	$1,115	$4,097	$2,806	23.78	0.04
2 x 4 studs, R-15 batt, R-5 1 in. polystyrene, ASHRAE minimum clg. Insulation	20.0	0.0	38.0	$1,742	$47	$1,281	$716	$1,997	$706	15.03	0.07
2 x 4 studs, R-15 batt, R-7.5 1.5 in. polystyrene, ASHRAE minimum clg. Insulation	22.5	0.0	38.0	$1,731	$58	$1,539	$716	$2,255	$964	16.63	0.06
2 x 4 studs, R-15 batt, R-10 2 in. polystyrene, ASHRAE minimum clg. Insulation	25.0	0.0	38.0	$1,716	$73	$1,860	$716	$2,576	$1,285	17.61	0.06
2 x 4 studs, R-15 batt, R-15 3 in. polystyrene, ASHRAE minimum clg. Insulation	30.0	0.0	38.0	$1,695	$94	$2,464	$716	$3,180	$1,889	20.09	0.05
2 x 6 Studs, R-21 Batt, 1 in. polystyrene, R-5, ASHRAE minimum clg. Insulation	26.0	0.0	38.0	$1,721	$68	$1,464	$1,115	$2,579	$1,288	18.94	0.05
2 x 6 Studs, R-21 Batt, 1.5 in. polystyrene, R-7.5, ASHRAE minimum clg. Insulatio	28.5	0.0	38.0	$1,706	$83	$1,799	$1,115	$2,914	$1,623	19.56	0.05
2 x 6 Studs, R-21 Batt, 2 in. polystyrene, R-10, ASHRAE minimum clg. Insulation	31.0	0.0	38.0	$1,698	$91	$2,120	$1,115	$3,235	$1,944	21.36	0.05
2 x 6 Studs, R-21 Batt, 3 in. polystyrene, R-15, ASHRAE minimum clg. Insulation	36.0	0.0	38.0	$1,675	$114	$2,981	$1,115	$4,096	$2,805	24.61	0.04
2 x 4 studs, ASHRAE 90.2 Baseline incorporated (R-5 continuous insulation)	20.0	0.0	38.0	$2,044	-	$1,204	$716	$1,920	-	-	-
2 x 6 studs, ASHRAE 90.2 Baseline incorporated (R-5 continuous insulation)	20.0	0.0	38.0	$2,033	$11	$1,204	$1,115	$2,319	$399	36.27	0.03
2 x 4 studs (ASHRAE), R-15 batt, R-7.5 1.5 in. polystyrene	22.5	0.0	38.0	$2,027	$17	$1,539	$716	$2,256	$335	19.73	0.05
2 x 4 studs (ASHRAE), R-15 batt, R-10 2 in. polystyrene	25.0	0.0	38.0	$2,013	$31	$1,860	$716	$2,576	$656	21.17	0.05
2 x 4 studs (ASHRAE), R-15 batt, R-15 3 in. polystyrene	30.0	0.0	38.0	$1,988	$56	$2,464	$716	$3,180	$1,259	22.49	0.04
2 x 6 studs (ASHRAE), R-21 batt, R-5 1 in. polystyrene	26.0	0.0	38.0	$2,016	$28	$1,464	$1,115	$2,579	$659	23.54	0.04
2 x 6 studs (ASHRAE), R-21 batt, R-7.5 1.5 in. polystyrene	28.5	0.0	38.0	$1,998	$46	$1,799	$1,115	$2,915	$994	21.62	0.05
2 x 6 studs (ASHRAE), R-21 batt, R-10 2 in. polystyrene	31.0	0.0	38.0	$1,988	$56	$2,120	$1,115	$3,235	$1,315	23.49	0.04
2 x 6 studs (ASHRAE), R-21 batt, R-15 3 in. polystyrene	36.0	0.0	38.0	$1,975	$69	$2,723	$1,115	$3,839	$1,918	27.80	0.04

(Source: homedepot.com for insulation, menards.com for framing, 2012)

Of all of the above-grade insulation scenarios covered, only a few could even be considered practical. For a homeowner, a reasonable payback would be considered 7 to 10 years; anything more would approach being pointless, but it would depend on how long the owner plans on living in the home. So, using a minimum payback period of 10 years leaves the owner with much to be desired through insulation improvements. None of the improvements considered produced a payback less than 11.95 years, and that was for the ¾ inch rigid sheathing option that is actually a minimum now required by code. Adding the R-5 rigid board insulation on top of the batt insulation instead of the sheathing has a payback of 13.08 years but, again, has to be done as the bare minimum for new construction because of the code requirements.

When considering a new residence that is being built to the minimum requirements of ASHRAE 90.2, the paybacks get a little worse. Improving the rigid board insulation from R-5 to R-7.5 on top of R-15 batt only saves $17 on the annual utility bills, a payback of 19.73 years. Increasing the continuous insulation to R-15 only saves $56 annually and increases the payback to 22.49 years. If the insulation was improved to R-21 and rigid board was added, the payback periods stayed approximately the same (21.62 years to 27.80). But, if ASHRAE envelope minimums were used as the base and the system and other parts of the construction were improved, or maximized, then the results looked a little better. Using the original model and decreasing the ceiling insulation provided a little more savings annually. A 2" x 4" stud wall with R-15 batt and R-5 continuous insulation (and more efficient systems and tighter construction) offers a payback of 15.03 years; possibly worth it for homeowners looking to settle down permanently. Improving the continuous insulation to R-7.5 or R-10 offers a payback period of 16.63 and 17.61 years, respectively. All of the above-grade insulation improvements are documented and can be found in Appendix C.

Therefore, improving the above-grade insulation of residence does not offer the type of payback that most homeowners would prefer considering the cost of the installation. If an owner wanted to spend the money to decrease monthly utility bills, he or she would not start seeing a payback until 15 years later depending on the efficiency of the other parts of the construction. Paying for more insulation does not appear to be worth it when it comes to the above-grade portion of the wall; no matter if the owner intends on staying for 50 years. But, the below-grade walls were also considered.

The below-grade walls for this residence consist of 8 inch concrete blocks with interior sheathing (R-1.3). An analysis was conducted to see how much energy could be saved if rigid board insulation was added to the original below-grade walls on the interior side and if the insulation was installed on new construction (interior or exterior or both). To calculate the payback period, the improvement cost had to be known. The cost of a 1 inch thick, R-5 perimeter insulation board is $11.65 per 4' x 8' panel according to Home Depot's website. The cost to cover the interior or exterior below-grade wall was then calculated based on the number of panels required (24 panels for 4' deep, 48 for 8' deep). Installing 1 inch, R-5 rigid board insulation 8 feet deep would cost $559. Installing 2 inches of rigid board insulation (R-10) 8 feet deep would double the cost to $1,118. The source data for the costs can be viewed in Appendix D. The resulting savings can be viewed in Figure 4-2 and they show that homeowners with below-grade areas, or basements, could save a lot of money on their annual utility bills by including insulation upon construction of the building.

Table 4-2 Below-Grade Wall Improvements and the Annual Savings

Enevelope Construction	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Utility Bill	Energy Bill Improvement	Initial Cost	Cost Difference	Payback	ROI	Source	Notes
Interior sheathing	15.0	1.3	42.0	$1,789	-	$0	-	-	-	-	None
Increase below-grade exterior bd. insulation to an R-value of 5, 4 ft deep	15.0	5.0	42.0	$1,706	$83	$280	$280	3.37	0.30	Home Depot	CelloFoam 1 in, R-5, 4' x 8' perimeter insulation board
Increase below-grade exterior bd. insulation to an R-value of 5, 8 ft deep	15.0	5.0	42.0	$1,666	$123	$559	$559	4.55	0.22	Home Depot	CelloFoam 1 in, R-5, 4' x 8' perimeter insulation board
Increase below-grade exterior bd. insulation to an R-value of 10, 4 ft deep	15.0	10.0	42.0	$1,687	$102	$559	$559	5.48	0.18	Home Depot	CelloFoam 2 in, R-10, 4' x 8' perimeter insulation board
Increase below-grade exterior bd. insulation to an R-value of 10, 8 ft deep	15.0	10.0	42.0	$1,632	$157	$1,118	$1,118	7.12	0.14	Home Depot	CelloFoam 2 in, R-10, 4' x 8' perimeter insulation board
Increase below-grade exterior bd. insulation to an R-value of 15, 8 ft deep	15.0	15.0	42.0	$1,615	$174	$1,678	$1,678	9.64	0.10	Home Depot	CelloFoam 3 in, R-15, 4' x 8' perimeter insulation board
Increase below-grade exterior bd. insulation to an R-value of 20, 8 ft deep	15.0	20.0	42.0	$1,605	$184	$2,237	$2,237	12.16	0.08	Home Depot	CelloFoam 4 in, R-20, 4' x 8' perimeter insulation board
ASHRAE 90.2 Baseline Incorporated, no below-grade insulation	20.0	0.0	38.0	$2,044	-$255	$0	-	-	-	-	
Add below-grade exterior bd. insulation to an R-value of 5, 4 ft deep (ASHRAE)	20.0	5.0	38.0	$1,949	$95	$280	$280	2.94	0.34	Home Depot	CelloFoam 1 in, R-5, 4' x 8' perimeter insulation board
Add below-grade exterior bd. insulation to an R-value of 5, 8 ft deep (ASHRAE)	20.0	5.0	38.0	$1,905	$139	$559	$559	4.02	0.25	Home Depot	CelloFoam 1 in, R-5, 4' x 8' perimeter insulation board
Increase below-grade exterior bd. insulation to an R-value of 10, 4 ft deep (ASHRAE)	20.0	10.0	38.0	$1,931	$113	$559	$559	4.95	0.20	Home Depot	CelloFoam 2 in, R-10, 4' x 8' perimeter insulation board
Increase below-grade exterior bd. insulation to an R-value of 10, 8 ft deep (ASHRAE)	20.0	10.0	38.0	$1,869	$175	$1,118	$1,118	6.39	0.16	Home Depot	CelloFoam 2 in, R-10, 4' x 8' perimeter insulation board
Increase below-grade exterior bd. insulation to an R-value of 15, 8 ft deep (ASHRAE)	20.0	15.0	38.0	$1,849	$195	$1,678	$1,678	8.60	0.12	Home Depot	CelloFoam 3 in, R-15, 4' x 8' perimeter insulation board
Increase below-grade exterior bd. insulation to an R-value of 20, 8 ft deep (ASHRAE)	20.0	20.0	38.0	$1,838	$206	$2,237	$2,237	10.86	0.09	Home Depot	CelloFoam 4 in, R-20, 4' x 8' perimeter insulation board

(Source: menards.com for perimeter board insulation)

Adding perimeter board insulation to the original construction would decrease the cost of the annual utility bills significantly. The insulation would have to be installed on the interior face of the basement walls, because the cost to excavate and add it to the exterior would be egregious and not recommended. For the first scenario, 1 inch CelloFoam perimeter insulation board was included in the model for the below-grade walls, but only 4 feet deep. This insulation board has a thermal resistance of R-5 and saved $83 on the utility bills. These savings offered a payback period of only 3.37 years, reasonable for homeowners willing to pay the installation cost. If this insulation board was installed the entire depth of the wall (8 feet), then the homeowner would save $123 a year offering a payback period of 4.55 years. The most money is saved when multiple layers of perimeter insulation board are installed on the below-grade walls and bring the R-value total to 20. This level of insulation saves $184 annually but the payback is 12.16 years, just outside the desired range. And, though it may be possible to add insulation on the interior side of the below-grade walls without much labor costs, more scenarios were analyzed assuming that the insulation would be installed on a new residence built up to the most recent code.

For new construction, the ASHRAE baseline model was used to evaluate improvements. Adding perimeter board insulation to the below-grade walls of the baseline model showed energy improvements that were very similar to those made to the original model, but slightly more pronounced. If a perimeter board (1-inch thick) with an R-value of 5 was installed 8 feet deep on the below-grade walls, then the annual utility bill would decrease by $95 and offers a payback of 2.94 years. For perimeter board thicknesses totaling R-20, $206 can be saved annually on bills. The payback for R-20 below-grade wall insulation is 10.86 years, slightly better than the payback for the original model, but still slightly out of the desired range. Additional information for this analysis can be found in Appendix C.

From this analysis, it became clear that below-grade insulation saves significant amounts of money when installed on a home. Adding or improving the below-grade insulation saves much more money when compared to improving the insulation of the above-grade frame walls. So, it can be reasonably concluded that adding below-grade insulation is a good idea and recommended for those owners interested in saving money on energy and getting a quick payback.

A third set of improvements were also made to the ceiling insulation of the residence and analyzed. The current ASHRAE 90.2 standard sets the minimum ceiling insulation at R-38, but the residence in this analysis has a greater thermal resistance at R-42. So, to see the difference in energy savings and to see what the payback period is for improvements, many different ceiling insulation scenarios were evaluated. The costs of the insulation material were found from the Menards website and from the RS Means book (“RSMeans”, 2011). The first set of improvements was made to the original model; utility bills were compared when the insulation exceeded R-42.

Using the original model, the ceiling insulation was increased and the results documented. When the ceiling insulation was increased from R-42 to R-43, only $2 were saved on the annual utility bills; a payback of 8.53 years when the improvement costs were considered. When the insulation increased from R-42 to R-49, $5 was saved, and increasing the ceiling insulation up to R-60 only saved $13 a year. The paybacks are small and manageable, but that is only because the cost to increase the insulation is not high; either way, the cost versus the savings is negligible. The complete data can be seen in Table 4-3. These savings cannot justify the cost of paying more for additional ceiling insulation, no matter what the payback.

Table 4-3 Above-Ceiling Insulation Improvements and the Annual Savings

Option	Enevelope Construction	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Utility Bill	Energy Bill Improvement	Insulation Cost	Initial Cost	Cost Difference	Payback
Original	Original above-ceiling insulation, loose-fill batt	15.0	0.0	42.0	$1,789	-	$1,023	$0	-	-
A	Increase ceiling insulation R-value by 1	15.0	0.0	43.0	$1,787	$2	$1,040	$1,040	$17	8.53
B	Increase ceiling insulation R-value by 7	15.0	0.0	49.0	$1,784	$5	$1,057	$1,057	$34	6.82
C	Increase ceiling insulation R-value by 18	15.0	0.0	60.0	$1,776	$13	$1,194	$1,194	$171	13.12
Older Homes	Remove ceiling insulation	15.0	0.0	0.0	$2,343	-$554	$0	$0	-$1,023	-
	R-11 batt insulation	15.0	0.0	11.0	$1,914	-$125	$256	$256	-$767	6.14
	R-13 batt insulation	15.0	0.0	13.0	$1,882	-$93	$290	$290	-$733	7.89
	R-21 batt insulation	15.0	0.0	21.0	$1,838	-$49	$512	$512	-$512	10.44
	R-30 batt insulation	15.0	0.0	30.0	$1,809	-$20	$850	$850	-$174	8.68
ASHRAE A	R-38 required	20.0	0.0	38.0	$2,044	-	$955	$955	-	-
ASHRAE B	Increase ceiling insulation R-value by 7 (ASHRAE)	20.0	0.0	45.0	$2,034	$10	$989	$989	$34	3.41
ASHRAE C	Increase ceiling insulation R-value by 11 (ASHRAE)	20.0	0.0	49.0	$2,030	$14	$1,057	$1,057	$102	7.31
ASHRAE D	Increase ceiling insulation R-value by 22 (ASHRAE)	20.0	0.0	60.0	$2,021	$23	$1,194	$1,194	$239	10.38

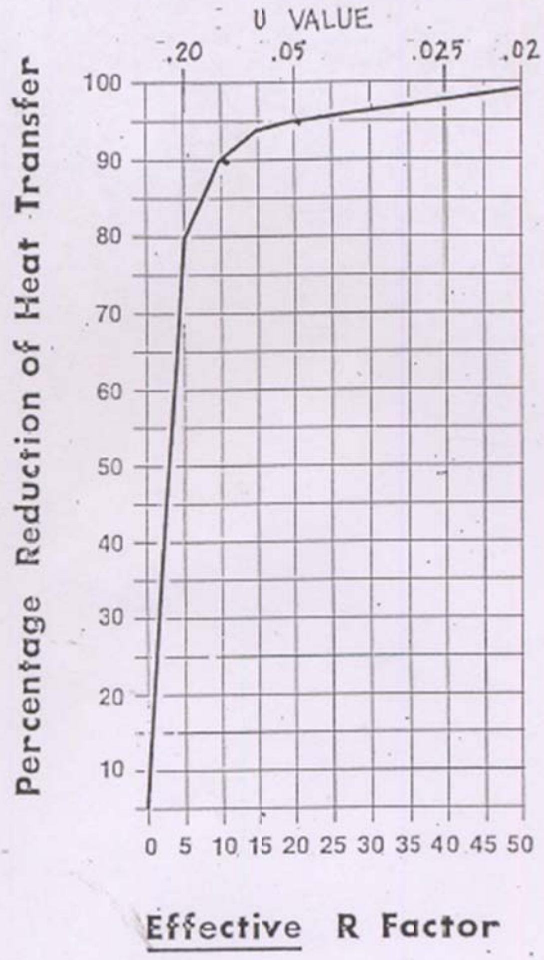
(Source: Homedepot.com for insulation costs)

To get a full understanding of the importance of ceiling insulation and its worth, the insulation savings were compared to homes that may have less insulation. If a home with all of the other inputs kept the same as the original model had zero ceiling insulation, the annual energy bill would cost about $550 more than if the R-42 insulation was installed. If only R-11 batt insulation was installed, the owner would lose $125 a year compared to the existing building with R-42 insulation. And, if only R-21 was installed, approximately $50 would be saved a year. But, an interesting point here is that if R-30 insulation was installed above the ceiling, then only $20 would be lost each year on the utility bills compared to the existing installation of R-42 above-ceiling batt insulation. Such a small amount could be made up in other areas, such as more energy efficient thermostatic setpoints, the cost of installing more thermally resistant insulation would become negligible.

From the results, it can be seen that increasing the ceiling insulation is not worth the cost after reaching R-30. But, R-30 is not up to code, so a minimum of R-38 is all that needs to be installed in homes in climate zone 4. Going above the minimum, baseline value would only save an owner $5 or $10 a year; dollars that could be made up by improving the residence’s construction or systems in other ways that would create more significant savings. In fact, this data supports a graphic from the homeowner’s teaching material displayed in Figure 4-1.

Figure 4-1 Efficiency of Insulation Chart from Homeowner

EFFICIENCY OF INSULATION



ENERGY SAVINGS

R	U	%
5	.20	80
10	.10	90
15	.066	93.4
20	.05	95
25	.04	96
30	.033	96.7
35	.028	97.2
40	.025	97.5
45	.022	97.8
50	.02	98

U VALUE Overall Heat Transmission Coefficient

The measurement of heat transmission or heat flow in B.T.U. per hour per square foot per degree Farenheit temperature difference through a combination of materials or building section.

This may be computed: $U = \frac{1}{R}$

This graphic shows that the insulation efficiency increases significantly from 0 to R-15, but then starts to level off. From R-15 to R-50, the efficiency only increases about 5%. This means that increasing the thermal resistance of the above-ceiling insulation is not a huge money-saver. ASHRAE 90.2 sets a minimum above-ceiling insulation value at R-38, but this graphic and the supporting data show that there is not a large difference between R-30 and R-60. So, it is safe to conclude that increasing insulation values above the code minimum does not provide an attractive payback.

Improving the ceiling insulation was also analyzed using the ASHRAE 90.2 baseline model created earlier. The results were the same as in the original model. Improving the above-ceiling insulation for a home built to comply with the ASHRAE 90.2 minimums would save very little money annually. If the insulation R-value was increased to 60, only $23 would be saved each year on energy; not worth it in the long-run. Later in this report, scenarios will be shown in which some of the best money-saving techniques are combined to lower the annual utility bills the most and reward the homeowner.

The fourth envelope alteration considered was changes to windows or glass. The type of window installed in a residence is critical and can really affect the annual energy bills for a home. The number of panes and the U-factor of the glass are the two major factors that affect yearly savings. The current residence has two window types: the below-grade windows have a U-value of 0.81 and the above-grade windows have a U-value of 0.50. The above-grade windows consist of a single pane window plus a storm window and some of them are single-hung and casement type. The below-grade windows only have a single pane and are sliding type. To make the calculations easier and more organized, a spreadsheet was created that grouped the above-grade and below-grade windows by U-value and then by visible transmittance. The shading coefficient was kept constant at 0.35.

The improvements to the window were made under the assumption that the windows would only be installed for new construction applications because the cost to replace windows would be exorbitant. New windows had to comply with ASHRAE 90.2 standards for windows construction; the U-values had to be at or below 0.35. Improvements made to the existing building were done for reference, but Table 4-4 displays the types of glass improvements explored for new residences. The ACCA Load Calculation manual was consulted for available window construction options and their respective U-values and used as the starting point for the glass improvements (though some do not comply with the ASHRAE 90.2 baseline). To get paybacks for these windows, however, a manufacturer had to be found with very basic window types.

Table 4-4 Window Improvements Made To ASHRAE 90.2 Baseline

No. of Pane	Window Construction	Shading Coefficient	Visible Transmittance	Casement U-Value	Double-Hung U-Value	First Floor U-Value	Basement U-Value	Utility Bill	Energy Bill Improvement	Initial Cost	Cost Increase	Payback	Source
1	Single Pane + Storm, Clear	0.35	0.81	-	-	0.50	0.81	$1,789	-	$6,520	-	-	ACCA
2	Clear Pane + Low e Pane	0.35	0.81	-	-	0.38	0.38	$1,745	-	$9,444	$0	-	Jeld-Wen
2	ASHRAE Baseline	0.35	0.81	-	-	0.35	0.35	$2,044	-	-	-	-	-
2	ASHRAE Baseline, Clear Pane + Low e Pane	0.35	0.81	-	-	0.38	0.38	$2,055	-$11	$7,252	-	-	Jeld-Wen
3	ASHRAE Baseline, Triple pane, 1/2" gap	0.35	0.81	0.27	0.27	0.27	0.27	$2,014	$30	$14,386	$4,942	164.72	Eagle
2	ASHRAE Baseline, Architect Series 11/16" Advanced Low-e IG with Argon	0.35	0.51	0.29	0.30	0.295	0.300	$2,022	$22	$11,765	$2,321	105.50	Pella
2	ASHRAE Baseline, Architect Series 11/16" SunDefense Low-e IG with Argon	0.35	0.47	0.29	0.29	0.290	0.300	$2,021	$23	$12,326	$2,882	125.30	Pella
2	ASHRAE Baseline, Architect Series 11/16" SunDefense Dual Low-e IG with Argon	0.35	0.44	0.26	0.26	0.260	0.300	$2,009	$35	$12,862	$3,418	97.66	Pella
2	ASHRAE Baseline, Architect Series Tinted; 11/16" Bronze Advanced Low-e IG w/ Argon	0.35	0.33	0.30	0.30	0.300	0.300	$2,024	$20	$12,326	$2,882	144.10	Pella
2	ASHRAE Baseline, Architect Series 11/16" Gray Advanced Low-e IG w/Argon	0.35	0.29	0.30	0.30	0.300	0.300	$2,024	$20	$12,326	$2,882	144.10	Pella
2	ASHRAE Baseline, A-Series, High-Performance Low-e 4 with Argon	0.35	0.71	0.25	0.25	0.250	0.300	$2,005	$39	$17,890	$8,446	216.56	Andersen
2	ASHRAE Baseline, 400 Series Woodwright® Insert Replacement Windows, HP Low-e4	0.35	0.54	0.28	0.30	0.290	0.300	$2,021	$23	$12,932	$3,488	151.65	Andersen
2	ASHRAE Baseline, 400 Series Woodwright® Insert Replacement Windows, HP Low-e4Sun	0.35	0.30	0.28	0.30	0.290	0.300	$2,021	$23	$12,932	$3,488	151.65	Andersen
2	ASHRAE Baseline, 400 Series Woodwright® Insert Replacement Windows, HP Low-e4SmartSun	0.35	0.49	0.27	0.29	0.280	0.300	$2,017	$27	$12,932	$3,488	129.19	Andersen
2	ASHRAE Baseline, 200 Series Tilt-Wash Double-Hung Windows, 400 Series Casement, Low-e	0.35	0.55	0.28	0.30	0.290	0.300	$2,021	$23	$9,522	$78	3.39	Andersen
2	ASHRAE Baseline, 200 Series Tilt-Wash Double-Hung Windows, 400 Series Casement, Low-e Smartsun	0.35	0.49	0.27	0.29	0.280	0.300	$2,017	$27	$9,522	$78	2.89	Andersen
2	ASHRAE Baseline, 200 Series Narroline Double-Hung Windows, 400 Series Casement, Low-e	0.35	0.55	0.28	0.30	0.290	0.300	$2,021	$23	$9,445	$1	0.04	Andersen
2	ASHRAE Baseline, 200 Series Narroline Double-Hung Windows, 400 Series Casement, Low-e Sun	0.35	0.31	0.28	0.30	0.290	0.300	$2,021	$23	$9,445	$1	0.04	Andersen

For the window types found in the ACCA manual, prices were found from Jeld-Wen and Eagle. Using all Jeld-Wen windows, the cost to install 3’ x 5’ double-hung and casement windows and 2’ x 2’ sliding type windows in a building typical to the one being analyzed was determined. The number of each window installed was not changed compared to the original residence: 14 casement windows, 11 double-hung windows (no single-hung are available in today’s market), and 3 sliding windows for the basement. The cost of installing clear, double-pane, low-e windows was calculated to be $9,444 according to a pricing quote by Jeld-Wen. And, because clear, double-pane windows is the most basic, or first, option for a building that would be built today, this is the price used as the baseline for all other building improvements. The U-value for this construction does not comply with ASHRAE, but it is close; only $11 more expensive than the baseline. The costs of each window type and the respective savings were compared to the cost of the Jeld-Wen clear, double-pane, low-e window and its utility bill savings.

With a baseline set, other window options were evaluated and the energy savings and payback periods of each were determined. A triple pane window from Eagle was the first improvement considered. The U-value for the center-of-glass is 0.27 for all window types and the annual energy saved only adds up to $30. The payback period for this window is 165 years; an extremely long time. Improving the windows above the baseline to 3 panes would cost more to install than it would save. Therefore, installing a triple-pane window would not be recommended due to the long payback period

The next set of window installations explored was from Pella. The only windows considered came from the Architect Series because it included wooden framed windows like the ones installed in the original residence and consistency was desired for this research. A double-pane, advanced low-e casement or double-hung window with argon has a U-value of 0.295 and 0.3, respectively. The basement window is a 10/20 series gliding, advanced low-e window with argon and no grille and maintained for all improvements. The U-value for the basement window is 0.30. Installing these windows would save $22 annually and offer a payback of 106 years. If SunDefense Low-e windows with argon (U-value=0.29) were installed in a new residence, $23 would be saved on the energy bills. The payback period for this window type is 125 years.

If SunDefense Dual Low-e windows with argon were installed, the owner would save $35 annually. The U-value for the casement and double-hung windows would average out to be 0.25 and offer a payback period of 97.66 years. Bronze Advanced, Low-e windows by Pella with argon save only $20 on the utility bills and offer a payback of 144 years. Installing Gray Advanced windows save the same on utility bills and offer the same payback. The U-value for both the Bronze and Gray Advanced window is 0.30. Pella offers windows with low U-values, but only marginal annual savings. The last set of windows considered was from Andersen.

Several Andersen windows were considered to compare savings. But, there were only two different levels of savings if the A-series is excluded: $23 and $27. The A-series, High-Performance, Low-e casement or double-hung window with argon saves $39. This A-Series window has a U-value of 0.25 and the complete installation would offer a payback of 217 years. The basement window used for all Andersen improvements was a 200 series sliding window and had a U-value of 0.30. The U-values for the other improvements alternate between 0.28 and 0.29 and lead to similar savings.

If 400 Series Woodwright windows were installed in a residence with different low-e protection, the annual savings would be around $23. The cost to install these windows would be close to $13,000 and offer paybacks of 150 years. If 200 Series Tilt-Wash, Double-Hung windows with Low-e protection were used with 400 Series casement windows; $23 to $27 would be saved. The cost to install such a configuration would be around $9,500, not much more than the baseline window installation. Therefore, the payback period for this installation would be very quick: around 3 years. Installing 200 Series Narroline, Double-Hung windows presents similar results. Only $23 to $27 is saved annually, but the payback period is almost zero because installing these types of windows is the same as installing the Jeld-Wen baseline. The complete data set can be viewed in Appendix C. The bottom line is, improving the glass or window construction does not offer lucrative paybacks in the long-run.

Improving the windows in a residence offers little in terms of payback, though the savings from reduced infiltration is not analyzed and therefore not accounted for. If the solar heat gain is all that is considered, a window with the best U-value only saves the owner $40 annually on utility bills. For windows, other factors should be considered when deciding which type to purchase. The cost to purchase and install windows is exorbitant and not much is saved by improving the glass. Therefore, the type of windows installed in a residence depends on what the homeowner prefers. The cheapest available can be chosen to save money immediately. Paying more for a window with a better U-value does not offer a significant increase in savings, but it does help. If aesthetics are important to the owner, then it is recommended that the windows be chosen according to how they look instead of how thermally resistant they are. This research has shown that improving glass is not recommended if energy savings are the goal.

The final envelope alteration that was explored involved the color of the roofing material. The material itself was not changed because it was assumed that most homeowners and homebuilders would install shingles on the roofs of their houses. The original roofing material for the residence consisted of medium, light brown shingles. To make conclusions about how the color of the roofing material affects the annual utility bills, the color of the shingles was changed in the eQuest model and the results were documented. When the color of the shingles was changed from light brown to dark brown, the cooling increased, the heating decreased, and $2 were saved annually. When the color was changed to a different medium color with the same ABS value, the cooling decreased, the heating increased, and $3 were lost annually. Similarly, when the color was changed to a lighter color (such as green) the cooling decreased, the heating increased, and $6 was lost annually. Changing the roof color from brown to rust red did not affect the energy bills.

The color of the roof does affect how heat is trapped in the attic of the house, but it is minimal. Saving a few dollars each year does not warrant a recommendation over what color of roofing material should be used in a home. The owner should choose whichever color he or she sees fit and can let aesthetics play a large part in the decision. Though it may seem logical that a lighter roofing material may save money more money on cooling and save money, the fact is that the change in color also affects the heating and balances itself out in the long-run, and not much money is saved.

System Improvements

Enhancements to the envelope were not the only adjustments made to the building. Improvements to the building's systems were also experimented with. The system improvements that were explored involved the HVAC system efficiency and the thermostatic setpoints.

The system installed in the residence is a 3-ton furnace with direct expansion (DX) cooling. The cooling system has a seasonal energy efficiency ratio (SEER) of 13 and the heating system has an annual fuel utilization efficiency of 94%. The cost of this system (on today's market) would be $1,127; a price obtained from Lennox (without a mark-up) that would be used to gauge the payback period when comparing higher efficiency systems. The efficiency information can be viewed in Table 4-5.

Table 4-5 HVAC System Efficiency Improvements

Option	System Details	SEER	AFUE	Utility Bill	Energy Bill Improvement	Initial Cost	Cost Difference	Payback	Source
Original	Original cooling SEER	13.0	94.0%	$1,789	-	$2,347	-	-	Owner
A	Improve SEER to 14	14.0	94.0%	$1,775	$14	$2,642	$295	21.07	Lennox
B	Improve SEER to 16	16.0	94.0%	$1,753	$36	$3,073	$726	20.17	Lennox
C	Improve SEER to 21	21.0	94.0%	$1,717	$72	$4,175	$1,828	25.39	Lennox
D	Improve AFUE to 98%	13.0	98.0%	$1,755	$34	$3,215	$2,295	67.50	Lennox
Older Homes	Low SEER	8.0	94.0%	$1,907	-$118			0.00	
	Low SEER	10.0	94.0%	$1,846	-$57			0.00	
	Low SEER	11.0	94.0%	$1,823	-$34			0.00	
	Low SEER	12.0	94.0%	$1,805	-$16			0.00	
	Low AFUE	13.0	80.0%	$1,941	-$152	$2,045	$1,127	-7.41	

(Source: Lennox)

When the SEER was increased from 13 to 14 in the original model, the change only lowered the annual utility bill by $10. In fact, for every increase of 1 SEER, the energy bill only decreased by $8 to $10. This is very interesting considering how many options there are available for the higher efficiency HVAC systems. The cost of an HVAC system with a SEER of 14, a coil of $300, and a 94% efficient furnace is $2,342 and produced a payback period of 21.07 years. A 16-SEER system costs $2,773 and has a payback period of 20.17 years. And, the last cooling system inspected had a SEER of 21, had a system cost of $3,875, and had a payback period of 25.39 years despite saving $72 a year on the utility bills.

The heating AFUE was also adjusted and the results were documented. To get a better understanding of the relevance of the heating efficiency, a lower efficiency furnace was used in place of the original system and the utility bills were compared. A furnace with an AFUE of 80% and a cost of $618 was inputted into the model as a minimum or worst-case option. This value was selected because of the minimum options listed in the ASHRAE 90.1 standard for commercial equipment, but the sizes matched the capacity that would be required for this particular building. With an 80% furnace, the annual utility bills cost $152 more than they would have with a 94% furnace. So, increasing the furnace efficiency by 14 percentage points decreases the annual utility bill by $152; roughly $10 a point like was the case for the SEER adjustments. If a furnace with a 98% AFUE is used, however, then the energy bill is only improved by $34. This high-efficiency system costs $870 more and subsequently leads to a payback period of 25.59 years.

After conducting this analysis, it became clear that improving the system efficiency is not worth it if initial costs and paybacks are concerned. Increasing the efficiency of either the heating or cooling side of the system does not produce large enough energy savings to warrant the improvements based off of the original model. Increasing the system efficiency in the ASHRAE 90.2 model showed larger savings.

Table 4-6 HVAC System Efficiency Improvements to ASHRAE 90.2 Baseline

Option	System Details	SEER	AFUE	Utility Bill	Energy Bill Improvement	Initial Cost	Cost Difference	Payback	Source	Notes
ASHRAE	Original cooling EER	9.3*	80.0%	$2,044	-	$2,045	-	-	Lennox	
ASHRAE	Improve SEER to 14	14.0	80.0%	$1,990	$54	$2,340	$295	5.46	Lennox	DX = $1422, Furnace = $619
ASHRAE	Improve SEER to 16	16.0	80.0%	$1,967	$77	$2,771	$726	9.43	Lennox	DX = $1853, Furnace = $620
ASHRAE	Improve SEER to 21	21.0	80.0%	$1,931	$113	$3,873	$1,828	16.18	Lennox	DX = $2955, Furnace = $621
ASHRAE	Improve SEER to 14	14.0	94.0%	$1,871	$173	$2,642	$597	3.45	Lennox	DX = $1422, Furnace = $920
ASHRAE	Improve SEER to 16	16.0	94.0%	$1,848	$196	$3,073	$1,028	5.24	Lennox	DX = $1853, Furnace = $921
ASHRAE	Improve SEER to 21	21.0	94.0%	$1,812	$232	$4,175	$2,130	9.18	Lennox	DX = $2955, Furnace = $922

When the SEER was increased from 13 to 14 in the ASHRAE 90.2 model (with a furnace efficiency of 80%), the change lowered the annual utility bill by $54, as seen in Table 4-6. A cooling system with a SEER of 16 saves $77 annually, while a system with a SEER of 21 saves $113. The payback periods for these potential efficiency improvements are 5.46 years, 9.43 years, and 16.18 years, respectively. If a furnace with an AFUE of 94% is incorporated into the ASHRAE 90.2 model, the savings are even larger. A condenser with a SEER of 14 saves $173, a SEER of 16 saves $196, and a SEER of $232 annually. The payback periods for these potential improvements are 3.45 years, 5.24 years, and 9.18 years, respectively; all are within the desirable range of paybacks.

After looking at potential system efficiency improvements using the ASHRAE 90.2 baseline model, the payback periods showed that increasing efficiency is worth it in most cases. Increasing the system efficiency of both the cooling condenser and the furnace yields the best results and largest savings. When building a new home or installing a new system, the bottom line is that a more efficient system will save more money when it comes to annual utility bills. Installing a cooling condenser with a SEER of 16 and a 94% efficient furnace could possibly save the homeowner around $200 annually and pay itself off in under 6 years. These types of savings would be desired by most homeowners

. Increasing system efficiency in the ASHRAE 90.2 baseline model saved more money than in the original model because of the starting efficiencies. The system installed in the existing residence is very efficient, and has been upgraded since first being installed. Improving cooling and heating efficiencies of the ASHRAE 90.2 baseline system offers the homeowner an opportunity to save a significant amount of money annually. The payback for high-efficiency systems is also very manageable. So, paying more initially for a more efficient system can save the homeowner money in the long-run.

The final system adjustments that were investigated and documented were made to the interior thermostatic setpoints. How much money can be made by keeping the interior temperature at a lower degree during the entire winter or at a higher degree during the summer? Plus, any changes made to the thermostatic setpoints to improve the system would not cost the homeowner or occupant any money to do so; it is a free improvement. The scenarios explored can be seen in Table 4-7.

Table 4-7 Interior Thermostatic Setpoint Adjustments

System Details	Cooling Setpoint (°F)	Heating Setpoint (°F)	Utility Bill	Energy Bill Improvement
Original Cooling & Heating Setpoints	75.0	74.0	$1,789	-
Increase cooling setpoint by 1	76.0	74.0	$1,798	-$9
Increase cooling setpoint by 2	77.0	74.0	$1,781	$8
Increase cooling setpoint by 3	78.0	74.0	$1,765	$24
Decrease cooling setpoint by 1	74.0	74.0	$1,780	$9
Decrease cooling setpoint by 2	73.0	74.0	$1,773	$16
Decrease cooling setpoint by 3	72.0	74.0	$1,766	$23
Decrease cooling setpoint by 4	71.0	74.0	$1,762	$27
Decrease cooling setpoint by 5	70.0	74.0	$1,759	$30
Decrease heating setpoint by 1	75.0	73.0	$1,773	$16
Decrease heating setpoint by 2	75.0	72.0	$1,731	$58
Decrease heating setpoint by 3	75.0	71.0	$1,692	$97
Decrease heating setpoint by 4	75.0	70.0	$1,656	$133
Decrease heating setpoint by 5	75.0	69.0	$1,623	$166
Decrease heating setpoint by 6	75.0	68.0	$1,591	$198
Increase heating setpoint by 1	75.0	75.0	$1,806	-$17

So, using the original model, the cooling setpoints were increased during the summer. When the thermostatic setpoint was set at 78°F, the cooling decreased, the heating increased, and $24 would be saved annually. This is not the monumental money saver expected from such a change; cooling is obviously not the governing factor. But, when the heating setpoint was lowered, the money savings were more pronounced.

If the thermostatic setpoint was lowered to 72°F during the winter, then both the cooling and heating decrease and $58 would be saved annually. If the thermostat was set at 70°F, then $133 would be saved annually, and a 68°F setpoint would lead to a savings of $198. All thermostat changes and results can be viewed in Appendix C.

These results favor the belief that the heating within a residence uses more energy than the cooling does because there are more heating hours in a year. Or, to put it another way, natural gas is more expensive than electricity. Lower setpoints in the winter can save significant energy and money whereas lower summer setpoints are not really worth it due to the negligible savings. But, if a lower heating setpoint was used with a higher cooling setpoint, then the money savings would be more significant. Combinations including this scenario and other construction improvements were then explored in more detail.

Money Saving Combinations

After exploring individual improvements to the residence's systems and construction, certain combinations were explored that would provide tangible information for homeowners and homebuilders to use. Improving the building shell or the HVAC system alone saves money, but if multiple options were considered, then there is a potential to save even more annually. With a model readily available, it was easy to evaluate an arrangement of different money saving techniques. The inputs were altered within the model to show how the annual utility bills changed when the construction or HVAC system were enhanced or "maxed" out. The combinations were analyzed under the assumption that a new residence was being built and the installation or implementation costs were not considered. The cost to install each combination would be roughly the same; the material cost is what separates them.

The eQuest model produced the respective output summaries for reference and different arrangements showed how much money could be saved for different improvements. Such data would be beneficial to those individuals that have control over the construction of their homes or for those that are interested in renovating. And, the data could show the complete money saving potential for a house built to the similar standards of the building focused on in this report or for a house built to the current (minimum) standards of ASHRAE 90.2. In fact, the annual utility bills for the existing residence and the ASHRAE 90.2 baseline are included here for reference.

Figure 4-2 Annual Utility Bill for Focal Residence

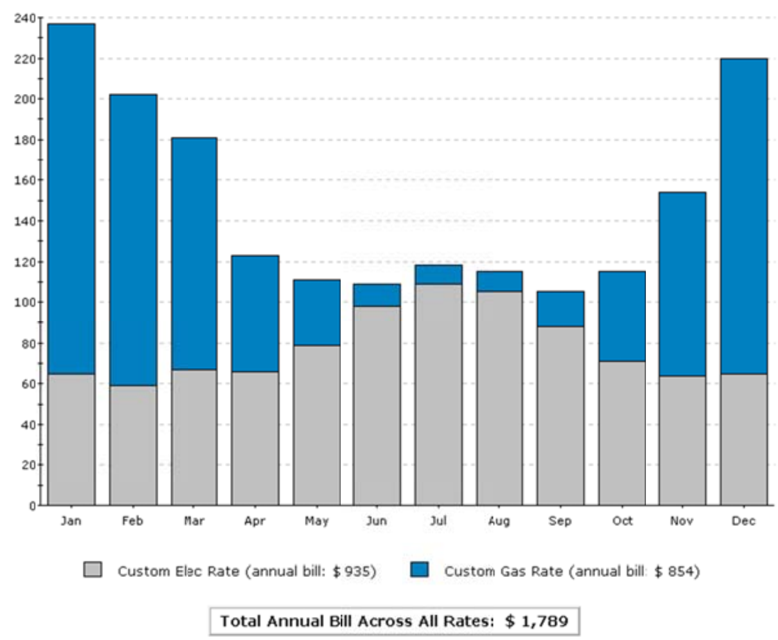
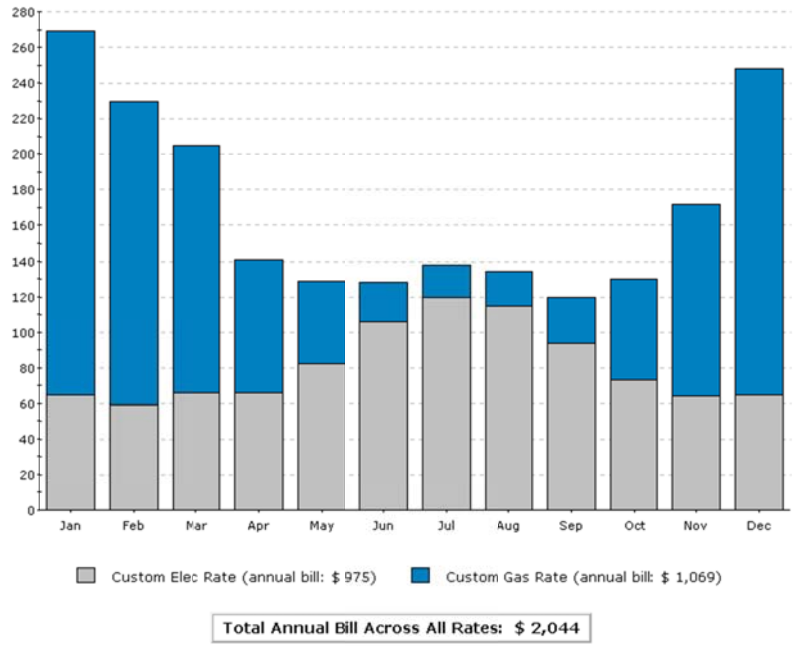


Figure 4-3 Annual Utility Bill for ASHRAE 90.2 Baseline Residence



By comparing these two models, it can be seen that the existing residence saves much more money annually than a residence built to the minimum standards of ASHRAE 90.2. But, this does not necessarily mean that the original residence is built tighter or more efficiently. There were very few details changed in the model, but the ones that were changed would be typical of a residence being built today.

There are a few reasons for the increase in utility bills. The construction of the ASHRAE 90.2 baseline model was looser than that of the existing residence. The infiltration ACH of the ASHRAE baseline model is 0.51 compared to 0.36 of the existing model. The code also anticipates more water being used in a day than what is actually being used in the focal residence. These two factors may cause the greatest money increase because the natural gas heating increased much more than the electrical cooling. Furthermore, the existing residence has more above-ceiling insulation than what is required by code (R-42 compared to the required R-38).

More factors could skew the data. The ASHRAE 90.2 baseline used the same lighting and miscellaneous loads as were inputted into the residence focused on in this report. This was done for consistency but, the fact is, different residences could see very different electrical loads from the plug and lighting loads. The number of people within the home could also change, and having more occupants within a building requires more conditioning. But, again, improvements were only made to the envelope and systems covered in ASHRAE 90.2; the rest of the inputs were left to make the two models easier to compare.

With the annual utility savings of the focal residence and ASHRAE baseline model displayed, the money-saving combinations could now be explored and compared. Improvements were made to the original residence for reference and then the ASHRAE 90.2 baseline model was enhanced to show what techniques would save owners the most money when constructing new homes. To save on the initial cost, and to get the fastest payback, the above-grade framing (and insulation), below-grade insulation, and thermostatic setpoints were the main areas adjusted throughout the model; other enhancements simply cost too much.

The first combination investigated involved 2” x 4” studs with only R-15 cavity insulation, R-5 below grade insulation installed 8 feet deep, and lower thermostatic setpoints during the winter months. The above-ceiling insulation was set at R-30 even though this particular scenario does not meet code. The lack of R-5 continuous insulation in the walls is also not up to code, but this issue will be addressed shortly. If the heating thermostatic setpoint was lowered from 74°F to 72°F and the below-grade insulation was considered, then $138 would be saved annually; even though R-30 ceiling insulation is lower than what is currently installed and not up to code. Lowering the setpoint even further to 70°F or 68°F saves $200 and $256, respectively. The payback periods for these options are very quick and reasonable; 4.05 years (72°F) to 2.18 years (68°F). This process is represented in Table 4-8.

Table 4-8 Annual Savings for Improvements Made to the Original Residence

Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Heating Setpoint	Utility Bill	Energy Bill Improvement	Payback
2 x 4 studs, R-5 exterior bd. below-grade insulation 8 feet deep	15.0	5.0	30.0	72°F	$1,651	$138	4.05
2 x 4 studs, R-5 exterior bd. below-grade insulation 8 feet deep	15.0	5.0	30.0	70°F	$1,589	$200	2.80
2 x 4 studs, R-5 exterior bd. below-grade insulation 8 feet deep	15.0	5.0	30.0	68°F	$1,533	$256	2.18
2 x 4 studs, R-5 exterior bd. below-grade insulation 8 feet deep, original ceiling insulatio	15.0	5.0	42.0	72°F	$1,633	$156	3.58
2 x 4 studs, R-5 exterior bd. below-grade insulation 8 feet deep, original ceiling insulatio	15.0	5.0	42.0	70°F	$1,571	$218	2.56
2 x 4 studs, R-5 exterior bd. below-grade insulation 8 feet deep, original ceiling insulatio	15.0	5.0	42.0	68°F	$1,517	$272	2.06
2 x 4 studs, R-10 exterior bd. below-grade insulation 8 feet deep, original ceiling insulati	15.0	10.0	42.0	72°F	$1,603	$186	6.01
2 x 4 studs, R-10 exterior bd. below-grade insulation 8 feet deep, original ceiling insulati	15.0	10.0	42.0	70°F	$1,545	$244	4.58
2 x 4 studs, R-10 exterior bd. below-grade insulation 8 feet deep, original ceiling insulati	15.0	10.0	42.0	68°F	$1,494	$295	3.79

If the above-ceiling insulation was set at what it is currently, R-42, and all other improvements were considered like before, then the utility bill is lowered only slightly. With an interior heating setpoint of 72°F and ceiling insulation that has an R-value 12 points higher than the first combination evaluated, $156 is saved annually; an improvement of only $18. The payback periods were nearly identical as well. So, improving the insulation this much does not appear to be worth it, but it is more than what ASHRAE 90.2 sets as the minimum (R-38), but still not what would be expected of such an increase.

The process of testing different combinations continued; the original wall construction was tested at lower thermostatic setpoints while the below-grade insulation was increased from R-5 to R-10. The annual savings, payback periods, and return-on-investments were all documented and available in Appendix C. Every combination analyzed will not be discussed, but they can be seen in Table 4-6 and compared to the annual utility bill of the original residence shown in Figure 4-2.

The next combination of enhancements looked at had an envelope that complied with ASHRAE 90.2, though not the systems, and can be viewed in Table 4-9. The frame stayed the same (2” x 4” studs), the cavity insulation inputted into the model was R-15 batt with additional R-5 continuous insulation and the ceiling insulation was set at R-38. The below-grade insulation started at R-5, 8 feet deep, and it was checked against the lower setpoints before increasing the below-grade insulation to R-10. With R-5 below-grade insulation and a setpoint of 68°F, the annual utility bill decreased by $290; a significant amount compared to the original bill and the summary of the savings can be seen in Figure 4-4. The payback for this particular configuration is also very manageable. If a residence were to be built up to the specified criteria and the setpoint kept at 68°F, the improvements would pay themselves off in 4.36 years. This period is deemed worth it if a timeframe of 7-10 years is classified as “good”.

Table 4-9 Annual Savings for Improvements Made to a Residence with an Envelope Compliant with ASHRAE 90.2

Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Heating Setpoint	Utility Bill	Energy Bill Improvement	Payback
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	72°F	$1,577	$181	6.99
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	70°F	$1,519	$239	5.29
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	68°F	$1,468	$290	4.36
2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	72°F	$1,547	$211	8.64
2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	70°F	$1,493	$265	6.88
2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	68°F	$1,446	$312	5.85
2 x 4 studs, ASHRAE 90.2 Envelope, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	72°F	$1,532	$226	10.55
2 x 4 studs, ASHRAE 90.2 Envelope, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	70°F	$1,480	$278	8.58
2 x 4 studs, ASHRAE 90.2 Envelope, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	68°F	$1,434	$324	7.36

Adding R-10 below-grade insulation was another possibility that was considered in Table 4-9. If the basement insulation is increased, the annual utility bill decreases by $312 at 68°F. The graphical utility bill output can be viewed in Figure 4-5. The payback for this particular option is

5.85 years; only 1.49 years more than the payback for R-5 below grade insulation. So, it can be concluded that adding below-grade insulation is relatively inexpensive and saves money almost immediately. And, lowering the heating thermostatic setpoint increases the speed of the payback because it is costs nothing to improve.

Maximizing the below-grade insulation does not save as much money as one would think, however. If the basement insulation is improved to R-15 and everything else remains the same, then only $324 is saved; $12 more than the bill for the residence with R-10 below-grade insulation. The payback is also reasonable at 7.36 years. Therefore, adding below-grade insulation saves a large amount of money in a short amount of time, but it is not necessary to increase the thermal resistance to the maximum R-15. The utility costs of R-5 and R-10 below-grade insulation applications are compared and shown in Figure 4-4 and 4-5

Figure 4-4 R-15 Batt and R-5 Continuous Above-Grade Insulation, R-38 Above-Ceiling Insulation, R-5 Below-Grade Insulation, and a Heating Setpoint of 68°F

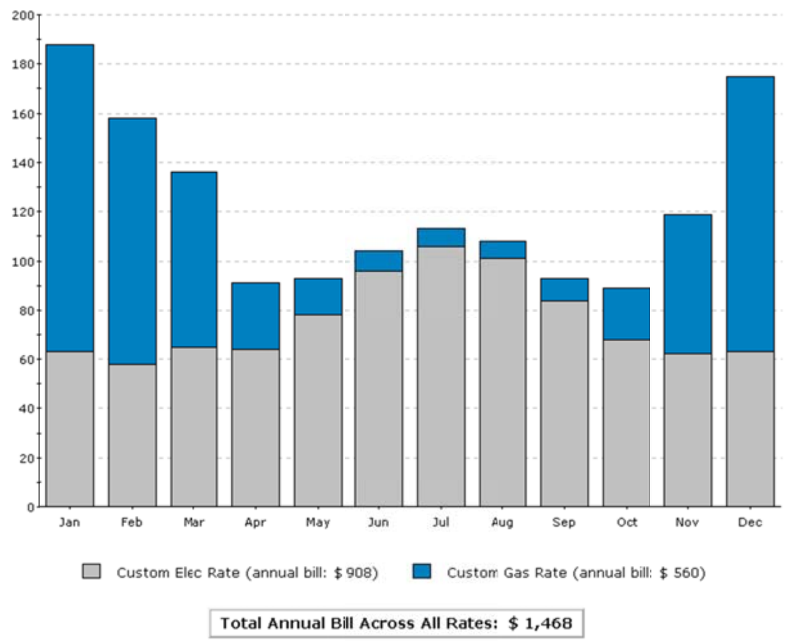
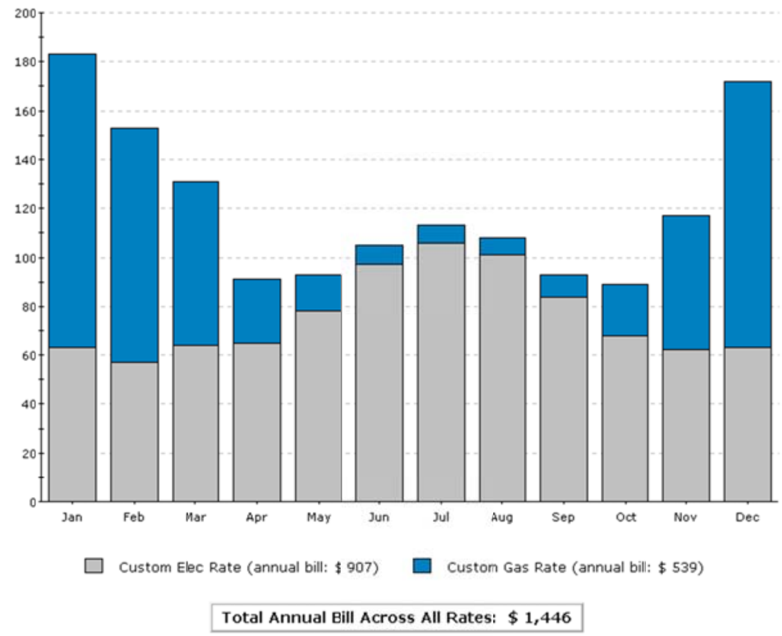


Figure 4-5 R-15 Batt and R-5 Continuous Above-Grade Insulation, R-38 Above-Ceiling Insulation, R-10 Below-Grade Insulation, and a Heating Setpoint of 68°F

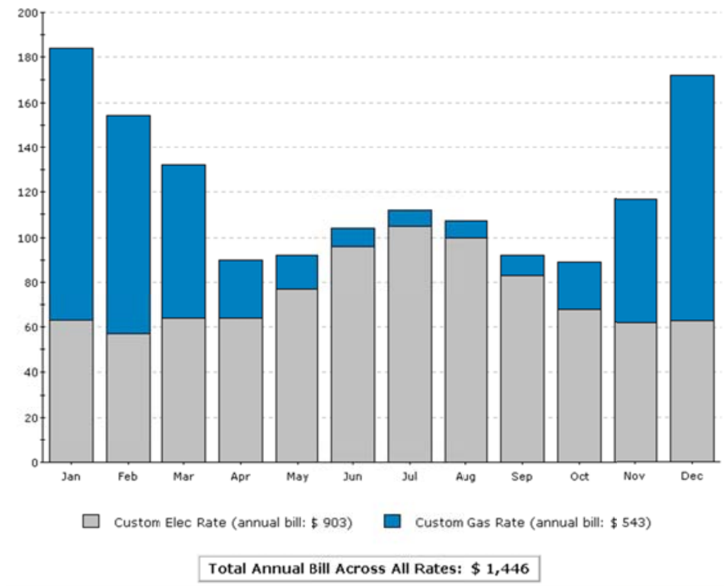


The improvements also expanded to include increased above-grade wall insulation. Though improving wall insulation alone proved to not be worth it according to the payback period, adding more continuous insulation to a wall along with other improvements did produce much quicker paybacks than what were evaluated earlier in this research. The last 2" x 4" wall assembly evaluated was for a wall with R-15 cavity insulation *and* R-10 continuous insulation as well. The below-grade insulation inputted into the model started at R-5 once more. The ceiling insulation input was kept the same and the winter setpoints were again stepped down from 72°F to 70°F to 68°F. After simulating the model, the outputs showed that the annual utility bill would decrease $206, $263, and $312, respectively. And, the payback period with a setpoint of 72°F fell within the desired range at 8.95 years while the payback for a model ran at 68°F offered a payback of 5.91 years. If the insulation thickness was doubled and R-10 below-grade insulation was used along with a setpoint of 68°F, the maximum amount of money saved on utility bills is $335 and the payback period is 7.17 years. So, improving other parts of the residence and including additional above-grade insulation in the model proved to be a combination worth considering for new houses. The utility bill summary of the maximum savings for a residence with only R-5 below-grade insulation can be seen in Table 4-10 and Figure 4-6.

Table 4-10 Annual Savings for a Residence with R-10 Continuous Insulation

Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Heating Setpoint	Utility Bill	Energy Bill Improvement	Payback
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	72°F	$1,552	$206	8.95
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	70°F	$1,495	$263	7.01
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	68°F	$1,446	$312	5.91
2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	72°F	$1,522	$236	10.18
2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	70°F	$1,469	$289	8.31
2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	68°F	$1,423	$335	7.17

Figure 4-6 R-15 Batt and R-10 Continuous Above-Grade Insulation, R-38 Above-Ceiling Insulation, R-5 Below-Grade Insulation, and a Heating Setpoint of 68°F



Installing R-10 below-grade insulation would lower the bills further, but only by about $20. So, increasing the below-grade insulation from R-5 to R-10 saves money, but the differential is not significant enough to warrant a definite conclusion. The cost of increasing the insulation does double, but the payback only increases 1.26 years when comparing R-5 insulation to R-10. Therefore, choosing between R-5 and R-10 below-grade insulation depends on the homeowner's preference. The owner can pay more to install better below-grade insulation (R-10) and receive a payback period that is only slightly longer than what is anticipated for R-5 insulation.

Improvements made to a 2" x 6" stud wall were also explored. Combinations involving above-grade cavity and continuous insulation, R-38 ceiling insulation, increasing below-grade insulation, and varying thermostatic setpoints were evaluated to provide homebuilders with additional information. Again, whether or not to build a residence using a 2" x 4" stud wall or a 2" x 6" stud wall is a serious question in the construction industry. This analysis will try and clear up some of the misconceptions about how the above-grade framing and its subsequent insulation affects the cost of a home. Only adjusting the framing was explored earlier in this research and proved to not be worth it, but here the framing was analyzed along with the other improvements discussed. All of the 2” x 6” options explored are listed in Table 4-11 along with their savings and payback periods.

Table 4-11 Annual Savings for a Residence with 2” x 6” Frame Walls

Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Heating Setpoint	Utility Bill	Energy Bill Improvement	Payback
2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	72°F	$1,570	$188	10.24
2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	70°F	$1,515	$243	7.92
2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	68°F	$1,460	$298	6.46
2 x 6 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	72°F	$1,540	$218	11.39
2 x 6 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	70°F	$1,490	$268	9.27
2 x 6 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	68°F	$1,440	$318	7.81
2 x 6 studs, ASHRAE 90.2 Envelope, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	72°F	$1,524	$234	13.01
2 x 6 studs, ASHRAE 90.2 Envelope, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	70°F	$1,475	$283	10.76
2 x 6 studs, ASHRAE 90.2 Envelope, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	68°F	$1,430	$328	9.28
2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	72°F	$1,564	$194	12.90
2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	70°F	$1,507	$251	9.97
2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	68°F	$1,456	$302	8.29
2 x 6 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	72°F	$1,534	$224	13.67
2 x 6 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	70°F	$1,481	$277	11.05
2 x 6 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	68°F	$1,434	$324	9.45

A 2” x 6” stud wall with R-15 cavity and R-5 continuous insulation, R-5 below grade insulation, R-38 ceiling insulation, and a heating setpoint of 72°F produces an annual utility bill that is $188 lower than the original base model’s. If the setpoint is lowered to 70°F or 68°F with the same conditions, then the bill is lowered by $243 and $298, respectively. The paybacks for each of these setpoints are, in order, 10.24, 7.92, and 6.46. So, these combinations (mostly) fall within the reasonable range set earlier. And, as expected, a building with a fixed, lower heating setpoint throughout the winter months produces the quicker payback.

Should the below-grade insulation be improved to R-10, 8 feet deep, then $328 would be saved at a setpoint of 68°F. Increasing the below-grade insulation further to R-15 only saves $317 annually, not a large improvement when the installation cost is considered. The payback for the R-10 scenario verses the R-15 scenario is 7.81 years to 9.28. But, the other paybacks for the R-15 below-grade insulation option fall outside the desired range; a 72°F setpoint offers a payback of 13.01 years and 70°F offers 10.76 years.

Considering all of the 2” x 6” stud wall options, the best options were decided by looking at the paybacks. The top paybacks for each construction scenario will always be with the lowest setpoint, but the 72°F setpoint option fell outside of the desired range in each case as well as most options including R-15 below-grade insulation. The option that provided the quickest payback was for the residence built with R-5 below-grade insulation and 68°F setpoint.

Having a setpoint of 70°F, with all other construction conditions the same, produced a reasonable payback of 7.92 years. This is a fairly quick payback as well and close to the payback of a residence with R-10 below-grade insulation and a 68°F setpoint (7.81 years). This data is showing that R-5 below-grade insulation is mandatory where saving money is concerned, but improving beyond that is not necessary. With a variety of construction techniques analyzed, it can be reasonably inferred that going beyond the code minimum for this climate zone is only necessary for the below-grade insulation. And, only the minimum insulation is really required because the payback periods are similar for the enhanced levels beyond. For occupants that do not wish to sacrifice so much comfort and lower their heating setpoint to 68°F, the 70°F option still saves a considerable amount of money and offers a reasonable payback. The cost to install thicker or more thermally resistant below-grade insulation basically cancels out the savings. The payback periods are roughly the same for improved below-grade insulation, but once beyond the payback period, more money will be saved, but only about $20 to $30 a year.

Increasing the above-grade continuous insulation was also explored, but the results maintained the same trend. Installing R-10 continuous insulation as opposed to R-5 insulation will save a little money annually, but not enough to warrant a recommendation. With a 2” x 6” stud wall, R-15 cavity insulation, R-10 continuous insulation, R-38 ceiling insulation, R-5 below-grade insulation, and a heating thermostatic setpoint of 72°F saves $194 on the annual utility bills. This is only a $6 increase compared to the R-5 continuous insulation application; not a desired conclusion. The payback for such an enhancement is 11.46 years and outside of the desired range. Therefore, the savings created by increasing the above-grade continuous insulation are not worth the cost of the installation.

A similar analysis was done using a model with inputs in accordance with the minimums set by ASHRAE 90.2. This was done because most of these improvements would be made to newly constructed residences that are built to the minimums set by the code. The improvements and their subsequent savings followed the same pattern as before, the only difference being the base utility bill. The ASHRAE 90.2 baseline model is not as energy efficient as the original model because of the tightness of construction and energy efficiency, therefore the initial utility bill costs more as seen in Figure 4-3. This model was used to show how the annual savings would be affected should a new residence be built to the bare minimums of the code and referenced when improvements are made to its construction and systems. It was created as a baseline and analyzed using the same combinations as before. The savings in each case were very close to those of the original residence, varying only slightly. The more popular combinations or the arrangements that provided the more significant paybacks are shown below and compared to those of the original model. But, it is important to note the energy bill improvements and payback periods of the ASHRAE 90.2 design because they are more applicable for conclusions drawn for new construction purposes. The initial utility bill for the original residence is $1,789 and the starting annual utility bill for a residence constructed up to the code requirements of ASHRAE 90.2 is $2,044.

Table 4-12 Comparison of the Original Residence's Annual Savings against a New Residence Built to the Standards of ASHRAE 90.2

Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Heating Setpoint	Utility Bill	Energy Bill Improvement	Payback
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	72°F	$1,577	$181	6.99
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	70°F	$1,519	$239	5.29
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	68°F	$1,468	$290	4.36
2 x 4 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	72°F	$1,855	$189	2.96
2 x 4 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	70°F	$1,786	$258	2.17
2 x 4 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	68°F	$1,726	$318	1.76

Table 4-12 through Table 4-18 compare the energy bill improvements between the existing building model and the ASHRAE 90.2 baseline. The top portion of the table displays the data for the original residence with only the insulation meeting or exceeding the requirements of ASHRAE 90.2. The bottom, shaded portion of the table displays the savings when the entire ASHRAE 90.2 baseline model is used. The only difference between the models in this case is the initial utility bill. The annual bill of the ASHRAE 90.2 model is more expensive because it uses minimums and a looser construction. Looking at the tables, it can be seen that the energy bill improvements are very similar for this combination of construction and system improvements. The savings for the combinations with setpoints at 70°F and 68°F only differ by about $20 in each case whereas the savings for the combinations with a setpoint of 72°F only differs by $8. The payback periods differ significantly because of the initial costs of the improvements; 6.99 years versus 2.96 years.

The ASHRAE baseline costs more than the original residence because the ASHRAE baseline includes the cost of the cavity insulation plus the continuous insulation and the above-ceiling insulation. Neither model accounts for the initial installation costs of the below-grade insulation because neither model has or requires it. The payback is calculated by dividing the difference between the initial cost and the improvement cost by the annual energy savings. Increasing the initial cost of the ASHRAE 90.2 model lowers the cost differential and lowers the payback. So, the payback period is much quicker for the ASHRAE model, but the energy bills are still higher than those of the original residence. But, because new construction is the focus when evaluating these improvements, the faster paybacks of the ASHRAE 90.2 analysis is what is important.

In the Table 4-13, the annual savings can be compared between residences built with R-10 below grade insulation:

Table 4-13 Comparison of the Original Residence's Annual Savings against a New Residence Built to the Standards of ASHRAE 90.2

Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Heating Setpoint	Utility Bill	Energy Bill Improvement	Payback
2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	72°F	$1,547	$211	8.64
2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	70°F	$1,493	$265	6.88
2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	68°F	$1,446	$312	5.85
2 x 4 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	72°F	$1,820	$224	4.99
2 x 4 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	70°F	$1,757	$287	3.90
2 x 4 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	68°F	$1,701	$343	3.26

Here the annual savings follow the same pattern as before. The initial savings for the 72°F setpoint are roughly the same, but increase as the setpoint is lowered. The ASHRAE 90.2 residence tends to save more money annually as improvements are made and this is probably explained by the higher initial cost of the construction. The payback periods for the ASHRAE model are also much quicker than those offered for the original residence which is desired, because new residences would be built up to the requirements of ASHRAE 90.2. And, comparing the two ASHRAE baseline model improvements only shows slight improvement when R-10 below-grade insulation is used compared to R-5. So, again, insulating a basement is recommended, but it does not have to be insulated with material passed R-5 according to this analysis. For this reason, only the combinations involving R-5 below-grade insulation will be discussed further.

In Table 4-14, the annual savings can be compared between residences built with R-10 continuous insulation instead of the R-5 minimum and R-5 below grade insulation:

Table 4-14 Comparison of the Original Residence's Annual Savings against a New Residence Built to the Standards of ASHRAE 90.2

Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Heating Setpoint	Utility Bill	Energy Bill Improvement	Payback
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	72°F	$1,552	$206	8.95
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	70°F	$1,495	$263	7.01
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	68°F	$1,446	$312	5.91
2 x 4 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	70°F	$1,758	$286	3.98
2 x 4 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	68°F	$1,701	$343	3.32
2 x 4 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	70°F	$1,728	$316	5.37
2 x 4 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	68°F	$1,674	$370	4.59

The only thermostatic setpoints explored for the ASHRAE 90.2 were 70°F and 68°F because these offered the most annual savings and quickest payback periods. In fact, installing R-10 continuous insulation improves the annual utility bill by the same amount as installing R-10 below-grade insulation, but with a worse payback. So, if it is desired to improve utility bills by $286 or $343, it is recommended that R-10 below-grade insulation be installed rather than improving the above-grade insulation because money can be made sooner. But, if R-10 below-grade insulation was installed, it would be worth it to also include R-10 continuous insulation. This combination would save $370 (or $316 at 70°F) annually according to the model and the payback period would be a desirable 4.59 years making this the most energy efficient combination.

In the Table 4-15, the annual savings can be compared between residences built with 2" x 6" frame walls:

Table 4-15 Comparison of the Original Residence's Annual Savings against a New Residence Built to the Standards of ASHRAE 90.2

Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Heating Setpoint	Utility Bill	Energy Bill Improvement	Payback
2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	72°F	$1,570	$188	10.24
2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	70°F	$1,515	$243	7.92
2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	68°F	$1,460	$298	6.46
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	72°F	$1,839	$205	5.95
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	70°F	$1,772	$272	4.48
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	68°F	$1,713	$331	3.68

A 2" x 6" stud wall was explored here. The wall cavity has R-15 batt insulation and R-5 continuous insulation. Again, the ASHRAE 90.2 model saves more money with improvements than the original model and with a faster payback. So, installing 2" x 4" stud walls instead of 2" x 6" stud walls appears to offer a shorter payback when combined with below-grade insulation and lower heating setpoints, though more money is saved annually. The cost of installation increases the payback for the 2" x 6" stud wall system, but the paybacks are still well within the desired range. The longest payback for this scenario is 5.95 years and the quickest is 3.68 years. Alone, installing a 2” x 6” frame wall with no other improvements is not recommended as the payback period is around 20 years. But, it is worth considering when combined with other money saving techniques.

In the Table 4-16, the annual savings can be compared between residences built with R-10 below grade insulation:

Table 4-16 Comparison of the Original Residence’s Annual Savings against a New Residence Built to the Standards of ASHRAE 90.2

Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Heating Setpoint	Utility Bill	Energy Bill Improvement	Payback
2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	72°F	$1,564	$194	12.90
2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	70°F	$1,507	$251	9.97
2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	68°F	$1,456	$302	8.29
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	72°F	$1,821	$223	8.06
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	70°F	$1,748	$296	6.07
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	68°F	$1,690	$354	5.08

In this analysis, the continuous insulation was increased to R-10 with 2” x 6” frame walls and R-15 batt insulation. The energy savings increase in much the same way as they did for the other improvements, but here is where significant differences started to show in the payback periods. The payback periods for the ASHRAE 90.2 model are still much lower than the original residence’s at 8.06, 6.07, and 5.08 years. But, the original residence’s payback periods are rather high and uncomfortable. The payback period when the interior heating setpoint was 72°F actually exceeded the acceptable range with a payback of 12.90 years. However, new construction is the focus and making these improvements for a residence built up to ASHRAE 90.2 requirements would save money and pay itself off within 7 years depending on the payback.

The table inserted here for reference shows the analysis involving 2” x 6” frame walls with a base cavity insulation of R-21 and additional continuous insulation. Table 4-17 shows improvements made to the continuous with more efficient cavity insulation.

Table 4-17 Annual Savings for a New Residence Built to the Standards of ASHRAE 90.2

Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Heating Setpoint	Utility Bill	Energy Bill Improvement	Payback
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	5.0	38.0	72°F	$1,821	$223	5.46
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	5.0	38.0	70°F	$1,755	$289	4.21
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	5.0	38.0	68°F	$1,697	$347	3.51
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	10.0	38.0	72°F	$1,787	$257	6.91
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	10.0	38.0	70°F	$1,726	$318	5.59
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	10.0	38.0	68°F	$1,672	$372	4.78
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	31.0	5.0	38.0	72°F	$1,801	$243	7.39
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	31.0	5.0	38.0	70°F	$1,736	$308	5.83
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	31.0	5.0	38.0	68°F	$1,680	$364	4.94
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	31.0	10.0	38.0	72°F	$1,767	$277	8.50
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	31.0	10.0	38.0	70°F	$1,706	$338	6.97
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	31.0	10.0	38.0	68°F	$1,655	$389	6.06

This data shows that installing 2” x 6” frame walls with R-21 batt insulation and R-5 or R-10 continuous insulation saves money and offers fast paybacks. In fact, installing R-21 batt and R-5 continuous insulation saves almost the same amount of money as the improvements made to the ASHRAE 90.2 baseline in Table 4.15. But, the payback period is shorter by about 2 years for each thermostatic setpoint. The return-on-investment is also greater for the combination involving the R-21 batt insulation and R-5 continuous insulation. Improving the continuous insulation up to R-10 would lower the annual utility bills even more while keeping the payback periods below the preset, desired threshold (7 to 10 years). R-10 below grade insulation was included in this table to show how the savings are increased by $20 to $30 depending on the setpoint. These are relatively small savings, but the payback periods for each are only slightly greater than those for the R-5 below-grade insulation combinations by about 1.00 year at each heating setpoint. For this reason, it may be worth it for a homeowner to consider this final option that includes 2” x 6” frame walls, R-21 cavity and R-10 continuous insulation, R-38 above-ceiling insulation, R-10 below-grade insulation, and a heating setpoint of either 72°F, 70°F, or 68°F. Up to $400 could be saved annually (maintaining a setpoint of 68°F) with a relatively low payback period of 6.06 years. The return-on-investment of this particular combination is a respectable 17%. A list of the money saving options available for a house meeting ASHRAE 90.2 standards (excluding efficiency improvements) can be found in Table 4-18.

Table 4-18 Complete Annual Savings for a New Residence Built to the Standards of ASHRAE 90.2

Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Heating Setpoint	Utility Bill	Energy Bill Improvement	Payback
2 x 4 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	72°F	$1,855	$189	2.96
2 x 4 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	70°F	$1,786	$258	2.17
2 x 4 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	68°F	$1,726	$318	1.76
2 x 4 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	72°F	$1,820	$224	4.99
2 x 4 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	70°F	$1,757	$287	3.90
2 x 4 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	68°F	$1,701	$343	3.26
2 x 4 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	70°F	$1,758	$286	3.98
2 x 4 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	68°F	$1,701	$343	3.32
2 x 4 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	70°F	$1,728	$316	5.37
2 x 4 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	68°F	$1,674	$370	4.59
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	72°F	$1,839	$205	5.95
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	70°F	$1,772	$272	4.48
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	68°F	$1,713	$331	3.68
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	72°F	$1,805	$239	7.44
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	70°F	$1,742	$302	5.89
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	68°F	$1,687	$357	4.98
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	72°F	$1,821	$223	8.06
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	70°F	$1,748	$296	6.07
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	68°F	$1,690	$354	5.08
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	72°F	$1,780	$264	8.92
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	70°F	$1,719	$325	7.25
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	68°F	$1,665	$379	6.22
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	30.0	5.0	38.0	72°F	$1,799	$245	10.85
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	30.0	5.0	38.0	70°F	$1,734	$310	8.57
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	30.0	5.0	38.0	68°F	$1,678	$366	7.26
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	30.0	10.0	38.0	72°F	$1,766	$278	11.57
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	30.0	10.0	38.0	70°F	$1,704	$340	9.46
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	30.0	10.0	38.0	68°F	$1,653	$391	8.23
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	5.0	38.0	72°F	$1,821	$223	5.46
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	5.0	38.0	70°F	$1,755	$289	4.21
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	5.0	38.0	68°F	$1,697	$347	3.51
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	10.0	38.0	72°F	$1,787	$257	6.91
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	10.0	38.0	70°F	$1,726	$318	5.59
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	10.0	38.0	68°F	$1,672	$372	4.78
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	31.0	5.0	38.0	72°F	$1,801	$243	7.39
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	31.0	5.0	38.0	70°F	$1,736	$308	5.83
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	31.0	5.0	38.0	68°F	$1,680	$364	4.94
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	31.0	10.0	38.0	72°F	$1,767	$277	8.50
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	31.0	10.0	38.0	70°F	$1,706	$338	6.97
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	31.0	10.0	38.0	68°F	$1,655	$389	6.06

Note: the baseline utility bill for the ASHRAE 90.2 model is $2,044.

Money saving combinations including system efficiency improvements were also considered. Table 4-19 shows the annual savings and payback periods for new residences that have more efficient HVAC systems, 2” x 4” stud walls, and fixed thermostatic setpoints (75°F cooling, 72°F heating). The above- and below-grade insulation was increased and compared to an HVAC system that had a 94% efficient furnace and a condenser of SEER 14, 16, and 21.

Table 4-19 Annual Savings for a New Residence Built to the Standards of ASHRAE 90.2 Including System Efficiency

Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Cooling SEER	Heating AFUE	Utility Bill	Energy Bill Improvement	Initial Cost	Improvement Cost	Cost Difference	Payback	ROI
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	14	94%	$1,704	$340	$5,299	$6,153	$854	2.51	0.40
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	16	94%	$1,681	$363	$5,299	$6,584	$1,285	3.54	0.28
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	21	94%	$1,643	$401	$5,299	$7,686	$2,387	5.95	0.17
2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	14	94%	$1,675	$369	$5,299	$6,712	$1,413	3.83	0.26
2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	16	94%	$1,652	$392	$5,299	$7,143	$1,844	4.70	0.21
2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	21	94%	$1,613	$431	$5,299	$8,245	$2,946	6.84	0.15
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	14	94%	$1,680	$364	$5,299	$6,732	$1,433	3.94	0.25
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	16	94%	$1,657	$387	$5,299	$7,163	$1,864	4.82	0.21
2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	21	94%	$1,619	$425	$5,299	$8,265	$2,966	6.98	0.14
2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	14	94%	$1,649	$395	$5,299	$7,291	$1,992	5.04	0.20
2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	16	94%	$1,627	$417	$5,299	$7,722	$2,423	5.81	0.17
2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	21	94%	$1,588	$456	$5,299	$8,824	$3,525	7.73	0.13

This data shows that building a residence with 2" x 4" stud walls, R-15 cavity insulation, R-5 continuous insulation, R-5 below-grade insulation board, R-38 above-ceiling insulation, and increasing levels of cooling efficiency saves a significant amount of money annually. Increasing the continuous, above-grade insulation and the below-grade insulation increases the annual savings. The payback periods for each of the combinations listed are reasonable and fall within the 7 to 10 year range. As the cost of improvements increases, the payback period lengthens, but no situation exceeds the 10 year maximum.

In Table 4-20, new residences with 2" x 6" frame walls, fixed thermostatic setpoints, and more efficient HVAC systems. The insulation was increased and the savings and paybacks were recorded just as they were in Table-19.

Table 4-20 Annual Savings for a New Residence Built to the Standards of ASHRAE 90.2 Including System Efficiency

Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Cooling SEER	Heating AFUE	Utility Bill	Energy Bill Improvement	Initial Cost	Improvement Cost	Cost Difference	Payback	ROI
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd below-grade insulation 8 feet deep	26.0	5.0	38.0	14	94%	$1,676	$368	$5,299	$6,812	$1,513	4.11	0.24
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd below-grade insulation 8 feet deep	26.0	5.0	38.0	16	94%	$1,653	$391	$5,299	$7,243	$1,944	4.97	0.20
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd below-grade insulation 8 feet deep	26.0	5.0	38.0	21	94%	$1,616	$428	$5,299	$8,345	$3,046	7.12	0.14
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd below-grade insulation 8 feet deep	26.0	10.0	38.0	14	94%	$1,647	$397	$5,299	$7,371	$2,072	5.22	0.19
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd below-grade insulation 8 feet deep	26.0	10.0	38.0	16	94%	$1,624	$420	$5,299	$7,802	$2,503	5.96	0.17
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd below-grade insulation 8 feet deep	26.0	10.0	38.0	21	94%	$1,586	$458	$5,299	$8,904	$3,605	7.87	0.13
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	31.0	5.0	38.0	14	94%	$1,659	$385	$5,299	$7,391	$2,092	5.43	0.18
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	31.0	5.0	38.0	16	94%	$1,637	$407	$5,299	$7,822	$2,523	6.20	0.16
2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	31.0	5.0	38.0	21	94%	$1,600	$444	$5,299	$8,924	$3,625	8.16	0.12
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd below-grade insulation 8 feet deep	31.0	10.0	38.0	14	94%	$1,629	$415	$5,299	$7,950	$2,651	6.39	0.16
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd below-grade insulation 8 feet deep	31.0	10.0	38.0	16	94%	$1,607	$437	$5,299	$8,381	$3,082	7.05	0.14
2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd below-grade insulation 8 feet deep	31.0	10.0	38.0	21	94%	$1,569	$475	$5,299	$9,483	$4,184	8.81	0.11

The cavity insulation was increased to R-21 and the continuous insulation was inputted as R-5 and R-10 in the ASHRAE 90.2 baseline model. The below-grade insulation was entered as R-5 and R-10 for each level of continuous insulation thickness as well. And, again, as the SEER rating was increased, the annual savings increased as well. The payback periods stayed in the desirable range and proved to be slightly shorter than the periods associated with 2" x 4" frame walls.

Including high-efficiency HVAC systems in a new residence with envelope improvements that exceed the ASHRAE 90.2 minimums can offer significant energy savings. The path to energy savings is through improving HVAC efficiency while limiting heat gain or heat loss through the building's envelope. The results listed in this section offer the top system and envelope combinations when achieving maximum savings is desired.

In review, there are many combinations worth executing if the homeowner is willing to pay more initially for better energy savings in the long-run. The savings increase as the thermal resistance of the envelope increases and, depending on the thermostatic setpoints, the paybacks offered by each are very manageable and worth installing. Increasing the efficiency of the HVAC systems also produces considerable annual savings. The analysis for system efficiency improvements was done with fixed thermostatic setpoints and yields money-savings with reasonable payback periods. If the heating setpoint was lowered even more with a more efficient cooling condenser, then there is the potential for more money-savings, obviously.

Chapter 5 - Conclusion

This data, as a whole, supports the theory that improving a residence's envelope while lowering the interior heating thermostatic setpoint will save money and offer a faster payback than the code minimum. This is assuming that the new house is similar in size and style and being built in Climate Zone 4A. The original residence analyzed does not have such low payback periods because it was built tighter than a newer residence in today's market. Therefore, new residences that are similar to the one analyzed and built to exceed the minimum requirements of ASHRAE 90.2 will save money and offer faster paybacks if the right improvements to the envelope are made.

Encouraging the builder to exceed the minimum code requirements could save the homeowner up to $300 or $400 annually if the right enhancements are made. Including R-5 below-grade insulation will conserve a large amount of energy and save money, and the installation cost is very low. For residences without basements, edge insulation would most likely save energy as well, but not as much as perimeter board below-grade insulation. Heat is lost through the floor construction or perimeter slab and the presence of insulation would greatly reduce the energy used to account for the loss. Increasing the below-grade insulation to R-10 is justifiable or even recommended if the owner is interested in paying more up front and planning for the long-term future.

As far as improving the above-grade insulation, it depends on the application. If only the cavity or continuous insulation exceeds the ASHRAE 90.2 baseline, then the improvement cannot be justified because of the long payback. But, if the above-grade insulation is improved in conjunction with other improvements, such as below-grade insulation, then the decision to upgrade the thermal resistance of the walls is warranted. Increasing the continuous insulation is expensive to install, but it does save money in the long-run, and the payback only decreases when combined with other techniques with shorter paybacks. If the cavity insulation was increased as well (only possible in a 2" x 6" stud wall) and the continuous insulation was increased, maximum savings can be achieved. Such improvements could only be made to new residence because the cost to improve an existing residence would be much too complicated and expensive.

The above-ceiling, or attic space, insulation is effective at the ASHRAE minimum of R-38. In truth, the minimum could be lowered to R-30 and even more money could be saved. The cost to improve ceiling insulation beyond R-30 is not really worth it (see Figure 4.1) because the efficiency of the insulation only increases by a percent or 2; a savings of roughly $10 on the annual utility bills. So, spending less on “lesser” insulation would offer a faster payback even though the annual utility bills would be a few dollars more. But, the minimum is set and does save money annually in this analysis, and money is what matters to homeowners.

In conclusion, there are two energy-efficient combinations worth considering; one for a 2” x 4” frame wall and one for a 2” x 6” frame. If a new residence is being built with 2” x 4” stud walls, then the following envelope criteria should be met to save money:

- R-15 above-grade wall cavity insulation
- R-10 continuous above-grade wall insulation
- R-10 below-grade perimeter board insulation (8 feet deep)
- R-38 above-grade (attic space) insulation

The heating thermostatic setpoint should also be set at either 72°F, 70°F, or 68°F to save even more money annually for no extra or installation cost. This setpoint should be fixed, or maintained, throughout the year at whichever temperature the occupants can tolerate. It is recommended that a programmable thermostat be installed that offers setback temperatures for the hours during the day in which the house is unoccupied. If the heating setpoint is maintained at 70°F, then $316 would be saved on the annual utility bills. If the thermostat is set and fixed at 68°F, then the annual utility bills would be lowered by $370 compared to the ASHRAE 90.2 baseline model.

If a new residence is being built with 2” x 6” stud walls, then the following envelope criteria should be met for the best results:

- R-21 above-grade wall cavity insulation
- R-10 continuous above-grade wall insulation
- R-10 below-grade perimeter board insulation (8 feet deep)
- R-38 above-grade (attic space) insulation

Again, the heating thermostatic setpoints should be set at one of the temperatures discussed earlier. These setpoints should be maintained throughout the year at whichever temperature the occupants can tolerate. If the heating setpoint is maintained at 72°F, then $277 would be saved on the annual utility bills. If the thermostat is set and fixed at 70°F, then the annual utility bills would be lowered by $338. But, if the thermostat is set at 68°F and the occupants just put on layers when cold, then $389 would be saved each year compared to the ASHRAE 90.2 baseline model.

A Manhattan, Kansas residence was analyzed and energy data was recorded to provide homeowners and homebuilders with information that may be useful when it comes to constructing a new residence in the same region and of a similar size and style. This report has sought to answer some of the questions or misconceptions that homeowners and homebuilders have when it comes to improving the construction or HVAC systems within residences in an effort to save money on energy. A common misconception is that the more insulation installed, the less heat loss or heat gain occurs. While this is the idea, the payback period is very large when considering the installation cost and overall efficiency of the system. The cost to improve the thermal resistance of the walls or ceiling is a lot of times much greater than the savings that will be provided. The efficiency of the insulation can only increase so much and it is quite gradual when reaching a certain point in certain applications. It would make sense for homeowners with basements to install below-grade insulation on the interior side of the basement wall, however, as money could be saved immediately at a relatively low cost. Another improvement for an existing home might be to lower the interior thermostatic setpoints during the winter months and subjecting the occupants to cooler temperatures in efforts to lower the annual energy use at no expense to the owners. Installing more efficient HVAC systems is also a way to improve annual utility bills.

If a new residence is being built and a high-efficiency HVAC system is to be installed, then the results of analysis support the following criteria:

- Furnace AFUE = 94%
- Cooling Condenser SEER = 14, 16, or 21
- 2” x 6” frame walls
- R-21 above-grade wall cavity insulation
- R-10 continuous above-grade wall insulation
- R-10 below-grade perimeter board insulation (8 feet deep)
- R-38 above-grade (attic space) insulation

There are many envelope and system combinations out there that save more money than the baseline or code minimum for new construction as well. Many combinations have been explored in this report to see what improvements might be worth the cost of installing. To answer this question, a payback period was listed with each combination and it was considered reasonable if the period was 10 years or less, but the sooner, the better. Paying more initially for some envelope enhancements or more efficient systems can save money immediately and allow the owner to recover the initial cost quickly in terms of profits from the energy savings.

The bottom line is that homeowners and homebuilders have to be proactive in the construction process to ensure that the necessary steps are taken to preserve money on their annual utility bills. If one has input on the building of their own home, then steps should be taken to save energy. Residential contractors should be encouraged to go above and beyond the code minimums in areas that affect the annual energy use the most. This report and the appendices have laid out certain individual and combined improvements that are worth the cost of installation to save homeowners money in the long-run. And, because most homes are built with the owner's intending to live in them permanently, or close to it, these improvements offer manageable and lucrative payback periods. This would allow the occupants to live comfortably for decades while money is continuously saved on energy.

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Appendix A - Load Calculation Support Data

All data used to calculate the heat transfer loads has been compiled in this section and is referenced throughout Chapter 2. The room load calculations, U-value calculations, and residential information can be found here.

Room Loads

The heat transfer loads were first calculated for all rooms within the residence. In Table A-1, the heat transfer calculations were done using a traditional commercial calculation process. The external, internal, and infiltration loads were calculated for each room in the residence. No ventilation was accounted for. In Table A-2, the room loads were calculated using the diversified lighting factors determined through anticipated hourly lighting in a single year. These tables were used as reference when making the energy model.

Table A-1 Room Load Calculation Workbook

Project:	Burton Residence				Page:	1	of	26	Date:	
Room:	101 Vestibule				Name:	Cody Knuth				
Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS – TRANSMISSION	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N				71.5				
		S				71.5				
		E				71.5				
		W	46	0.06	2.76	71.5	17	79	218	197
						71.5				
	Glass		24	0.79	18.96	71.5	17	22.6	428	1356
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors		42	0.365	15.33	71.5	17	22.6	346	1096
						71.5				
						71.5				
7S,7T	ROOF/CEILING		104	0.0229	2.38	71.5	17	58	138	170
7V,17	FLOOR					71.5				
						TRANSMISSION SUBTOTALS			1131	2819
EXTERNAL LOADS – SOLAR	ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows		N						
		doors								
	GLASS	windows		S						
		doors								
	GLASS	windows		E						
		doors								
	GLASS	windows	24	W	0.35	116			974	
		doors								
							SOLAR SUBTOTAL		974	
INTERNAL LOADS – ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts						CLG SENS LOAD	
	104	0.769	80		Incand.	Watts x 3.413 = BTUh			273	
					Fluor.	Watts x 4.1 = BTUh				
						Watts x 3.413 = BTUh				
							ELECT SUBTOTAL		273	
INTERNAL LOADS – PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD	
INTERNAL LOADS – EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12				
					EQUIPMENT SUBTOTALS					
INFILT	Tbl 13A & 13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG	6.933333	Q_L = CFM x .69 x ΔG		71.5	22.6	40	191.36	169	
	Space HTG	6.933333	Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			535
	Door CLG				71.5	22.6	40			
	Door HTG				71.5	22.6	40			
					INFILTRATION SUBTOTALS			191.36	169.2288	535.392
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration								191	2548	3355
									CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)									118	89
VENT	Tbl 14 ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG		71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			
					VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load										
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =					0.23			191	2548	3355

Project:		Burton Estate				Page:	2	of	26	Date:	
Room:		102 Kitchen				Name:	Cody Knuth				
Cooling: Outside db			97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db			2.5	*Inside db*	74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS	TRANSMISSION	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
		Wall	N	73	0.06	4.38	71.5	18	33	145	313
			S	51.75	0.061	3.16	71.5	18	37	117	226
			E				71.5				
			W				71.5				
							71.5				
		Glass		19.25	0.5	9.63	71.5	18	22.6	218	688
							71.5		22.6		
		Partitions		100	0.06	6.00	37	18	22.6		222
							71.5		22.6		
		Doors					71.5				
							71.5				
							71.5				
	7S,7T	ROOF/CEILING		225	0.0229	5.15	71.5	18	58	299	368
	7V,17	FLOOR					71.5				
							TRANSMISSION SUBTOTALS			778	1817
	SOLAR	ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
		GLASS	windows	7	N	0.35	32			78	
			doors								
		GLASS	windows	12.25	S	0.35	124			532	
			doors								
		GLASS	windows		E						
			doors								
		GLASS	windows		W						
			doors								
								SOLAR SUBTOTAL		610	
INTERNAL LOADS	ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts						CLG SENS LOAD	
		225	0.355556	80		Incand.	Watts x 3.413 = BTUh			273	
		225		80		Fluor.	Watts x 4.1 = BTUh			328	
							Watts x 3.413 = BTUh				
								ELECT SUBTOTAL		601	
	PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD	
	EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12				
		1		3200	Refrig, MW & Range					3200	
		1	3010	1040	Dishwasher				3010	1040	
						EQUIPMENT SUBTOTALS			3010	4240	
INFILT		Tbl 13A & 13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Space CLG	15	Q_L = CFM x .69 x ΔG		71.5	22.6	40	414	366	
		Space HTG	15	Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			1158
		Door CLG				71.5	22.6	40			
		Door HTG				71.5	22.6	40			
						INFILTRATION SUBTOTALS			414	366.12	1158.3
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration									3424	6595	2976
										CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)										305	79
VENT		Tbl 14 ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
				Q_L = CFM x .69 x ΔG		71.5	22.6	40			
				Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			
						VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load											
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =						0.83			3424	6595	2976

Project:	Burton Estate			Page:	3	of	26	Date:		
Room:	103 Pantry			Name:	Cody Knuth					
Cooling: Outside db	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40	
Heating: Outside db	2.5	*Inside db*	74	*Re: Tbl 1*						

EXTERNAL LOADS — TRANSMISSION

	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	N				71.5				
		S				71.5				
		E				71.5				
		W				71.5				
						71.5				
	Glass					71.5		22.6		
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		12	0.0229	0.27	71.5		58	16	20
7V,17	FLOOR					71.5				
								TRANSMISSION SUBTOTALS	16	20

EXTERNAL LOADS — SOLAR

ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF		BTUh COOLING LOAD
GLASS	windows		N				
	doors						
GLASS	windows		S				
	doors						
GLASS	windows		E				
	doors						
GLASS	windows		W				
	doors						
						SOLAR SUBTOTAL	

INTERNAL LOADS — ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
12	1	12		Incand.	Watts x 3.413 = BTUh	41
40				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
					ELECT SUBTOTAL	41

INTERNAL LOADS — PEOPLE / EQUIP

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea				CLG LAT LOAD	CLG SENS LOAD
EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12		
					EQUIPMENT SUBTOTALS		

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG	0.8	Q_L = CFM x .69 x ΔG	71.5	22.6	40	22.08	20	
Space HTG	0.8	Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			62
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
					INFILTRATION SUBTOTALS	22.08	19.5264	61.776

Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration	22	76	81
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		4	2

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
					VENTILATION SUBTOTALS			

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load				
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.01	22	76	81

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Room:	104 Sun Room				Name:	Cody Knuth				
Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS / TRANSMISSION		EXPOS-URE					July	ΔT or	COOLING	HEATING
	ITEM		AREA	U	U X A	HTG ΔT	TIME	ETD	LOAD	LOAD
	Wall	N	72	0.06	4.32	71.5	17	33	143	309
		S				71.5				
		E	56	0.06	3.36	71.5	17	34	114	240
		W	56	0.06	3.36	71.5	17	79	265	240
						71.5				
	Glass		105	0.5	52.50	71.5	17	22.6	1187	3754
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors		17.62	0.365	6.43	71.5	17	22.6	145	460
						71.5				
						71.5				
7S,7T	ROOF/CEILING		170.333	0.0229	3.90	71.5	17	58	226	279
7V,17	FLOOR					71.5				
							TRANSMISSION SUBTOTALS		2080	5282
SOLAR									BTUh	BTUh
				EXPOS-	Tbl 2A,2B	Tbl 3			COOLING	HEATING
	ITEM		AREA	URE	SF	SHGF			LOAD	LOAD
	GLASS	windows	40	N	0.35	32			448	
		doors								
	GLASS	windows		S						
		doors								
	GLASS	windows	32.5	E	0.35	164			1866	
		doors								
	GLASS	windows	32.5	W	0.35	156			1775	
		doors								
							SOLAR SUBTOTAL		4088	
INTERNAL LOADS / ELECT	LIGHTS / POWER	or W/SF	Total Watts						CLG SENS LOAD	
	170.33	0.793	135		Incand.	Watts x 3.413 = BTUh			461	
					Fluor.	Watts x 4.1 = BTUh				
						Watts x 3.413 = BTUh				
							ELECT SUBTOTAL		461	
PEOPLE	Tbl 15	Table 10								
	# of PEOPLE	LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD	
EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12				
						EQUIPMENT SUBTOTALS				
INFILT	Tbl 13A & 13B						CLG	CLG LAT	CLG SENS	HEATING
	ITEM	CFM			HTG ΔT	CLG ΔT	ΔG	LOAD	LOAD	LOAD
	Space CLG	11.35553	Q_L = CFM x .69 x ΔG		71.5	22.6	40	313.4127	277	
	Space HTG	11.35553	Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			877
	Door CLG				71.5	22.6	40			
	Door HTG				71.5	22.6	40			
					INFILTRATION SUBTOTALS			313.4127	277.1659	876.874
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration								313	6906	6159
									CLG CFM	HTG CFM
	Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)								320	163
VENT	Tbl 14						CLG	CLG LAT	CLG SENS	HEATING
	ITEM	CFM			HTG ΔT	CLG ΔT	ΔG	LOAD	LOAD	LOAD
			Q_L = CFM x .69 x ΔG		71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			
					VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load										
	Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =				0.60			313	6906	6159

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Room:	105 Dining Room	Name:	Cody Knuth				

Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains* 40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*				

EXTERNAL LOADS – TRANSMISSION	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	July TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	N	8	0.06	0.48	71.5	10	20	10	34
		S				71.5				
		E	64.667	0.06	3.88	71.5	10	62	241	277
		W				71.5				
						71.5				
	Glass		36.667	0.5	18.33	71.5	10	22.6	414	1311
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		158.338	0.0229	3.63	71.5	10	58	210	259
7V,17	FLOOR					71.5				
								TRANSMISSION SUBTOTALS	875	1882

EXTERNAL LOADS – SOLAR	ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF		COOLING LOAD
	GLASS	windows		N				
		doors						
	GLASS	windows		S				
		doors						
	GLASS	windows	64.667	E	0.35	164		3712
		doors						
	GLASS	windows		W				
		doors						
							SOLAR SUBTOTAL	3712

INTERNAL LOADS – ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
	158.34	1.21	192		Incand.	Watts x 3.413 = BTUh	654
					Fluor.	Watts x 4.1 = BTUh	
						Watts x 3.413 = BTUh	
						ELECT SUBTOTAL	654

INTERNAL LOADS – PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea				CLG LAT LOAD	CLG SENS LOAD

INTERNAL LOADS – EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12	CLG LAT LOAD	CLG SENS LOAD
						EQUIPMENT SUBTOTALS		

INFILT	Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG	10.55587	Q_L = CFM x .69 x ΔG	71.5	22.6	40	291.3419	258	
	Space HTG	10.55587	Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			815
	Door CLG			71.5	22.6	40			
	Door HTG			71.5	22.6	40			
					INFILTRATION SUBTOTALS		291.3419	257.6476	815.124

Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration	291	5498	2697
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		255	71

VENT	Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG	71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
					VENTILATION SUBTOTALS				

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load				
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.48	291	5498	2697

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Room:		106 Living Room				Name:	Cody Knuth				
Cooling:		*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating:		*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS	TRANSMISSION	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
		Wall	N				71.5				
			S				71.5				
			E	151.943	0.06	9.12	71.5	10	62	565	652
			W				71.5				
							71.5				
		Glass		34.7	0.5	17.35	71.5	10	22.6	392	1241
							71.5		22.6		
		Partitions					71.5		22.6		
							71.5		22.6		
		Doors					71.5				
							71.5				
							71.5				
	7S,7T	ROOF/CEILING		342.32	0.0229	7.84	71.5	10	58	455	560
	7V,17	FLOOR					71.5				
							TRANSMISSION SUBTOTALS			1412	2453
	SOLAR	ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
		GLASS	windows		N						
			doors								
		GLASS	windows		S						
			doors								
		GLASS	windows	34.7	E	0.35	164			1992	
			doors								
		GLASS	windows		W						
			doors								
								SOLAR SUBTOTAL		1992	
INTERNAL LOADS	ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts						CLG SENS LOAD	
		342.32	0.497	170		Incand.	Watts x 3.413 = BTUh			581	
						Fluor.	Watts x 4.1 = BTUh				
							Watts x 3.413 = BTUh				
								ELECT SUBTOTAL		581	
	PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD	
	EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12				
						EQUIPMENT SUBTOTALS					
INFILT		Tbl 13A & 13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Space CLG	22.82133	Q_L = CFM x .69 x ΔG		71.5	22.6	40	629.8688	557	
		Space HTG	22.82133	Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			1762
		Door CLG				71.5	22.6	40			
		Door HTG				71.5	22.6	40			
						INFILTRATION SUBTOTALS			629.8688	557.0231	1762.263
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration									630	4541	4215
										CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)										210	112
VENT		Tbl 14 ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
				Q_L = CFM x .69 x ΔG		71.5	22.6	40			
				Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			
						VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load											
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =						0.43			630	4541	4215

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Room:	107 Master Bathroom			Name:	Cody Knuth				
Cooling: Outside db	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db	2.5	*Inside db*	74	*Re: Tbl 1*					

EXTERNAL LOADS – TRANSMISSION	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	July TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	N				71.5				
		S				71.5				
		E	63.64	0.06	3.82	71.5	10	62	237	273
		W				71.5				
						71.5				
	Glass		3	0.5	1.50	71.5	10	22.6	34	107
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		52.275	0.0229	1.20	71.5	10	58	69	86
7V,17	FLOOR					71.5				
	TRANSMISSION SUBTOTALS								340	466

EXTERNAL LOADS – SOLAR	ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF	BTUh COOLING LOAD
	GLASS	windows		N			
		doors					
	GLASS	windows		S			
		doors					
	GLASS	windows	3	E	0.35	164	172
		doors					
	GLASS	windows		W			
		doors					
	SOLAR SUBTOTAL						172

INTERNAL LOADS – ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
	52.275	1.91	100		Incand.	Watts x 3.413 = BTUh	341
					Fluor.	Watts x 4.1 = BTUh	
						Watts x 3.413 = BTUh	
	ELECT SUBTOTAL						341

INTERNAL LOADS – PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea			CLG LAT LOAD	CLG SENS LOAD
	2	200	250			400	500
EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12	
	EQUIPMENT SUBTOTALS					400	500

INFILT	Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG	3.485	Q_L = CFM x .69 x ΔG	71.5	22.6	40	96.186	85	
	Space HTG	3.485	Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			269
	Door CLG			71.5	22.6	40			
	Door HTG			71.5	22.6	40			
	INFILTRATION SUBTOTALS						96.186	85.06188	269.1117
	Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration						496	1438	735
								CLG CFM	HTG CFM
	Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)							67	19

VENT	Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG	71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
	VENTILATION SUBTOTALS								
	Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load								
	Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =			0.16			496	1438	735

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Room:	108 Master Bedroom				Name:	Cody Knuth			
Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains* 40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*				

EXTERNAL LOADS

TRANSMISSION

	ITEM	EXPOS-URE	AREA	U	U X A	HTG ΔT	Aug TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	N				71.5				
		S	114.664	0.06	6.88	71.5	14	57	392	492
		E	83.75	0.06	5.03	71.5	14	38	191	359
		W				71.5				
						71.5				
	Glass		12.25	0.5	6.13	71.5	14	22.6	138	438
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		172	0.0229	3.94	71.5	14	58	228	282
7V,17	FLOOR					71.5				
	TRANSMISSION SUBTOTALS								950	1571

SOLAR

ITEM		AREA	EXPOS-URE	Tbl 2A,2B SF	Tbl 3 SHGF	BTUh COOLING LOAD
GLASS	windows		N			
	doors					
GLASS	windows		S			
	doors					
GLASS	windows	12.25	E	0.35	164	703
	doors					
GLASS	windows		W			
	doors					
SOLAR SUBTOTAL						703

INTERNAL LOADS

ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
172	0.46	79		Incand.	Watts x 3.413 = BTUh	270
				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
ELECT SUBTOTAL						270

PEOPLE / EQUIP

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea				CLG LAT LOAD	CLG SENS LOAD
1	200	250				200	250
EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12		
EQUIPMENT SUBTOTALS						200	250

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG	11.46667	Q_L = CFM x .69 x ΔG	71.5	22.6	40	316.48	280	
Space HTG	11.46667	Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			885
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
INFILTRATION SUBTOTALS						316.48	279.8784	885.456

	CLG LAT	CLG SENS	HEATING
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration	516	2453	2456
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		114	65

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
VENTILATION SUBTOTALS								

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load					
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.25		516	2453	2456

Project:	Burton Estate				Page:	9	of	26	Date:	
Room:	109 Master Closet				Name:	Cody Knuth				
Cooling: Outside db		97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db		2.5	*Inside db*	74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS / TRANSMISSION	ITEM	EXPOS-URE	AREA	U	U X A	HTG ΔT	TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N				71.5				
		S				71.5				
		E				71.5				
		W				71.5				
						71.5				
	Glass					71.5		22.6		
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		30	0.0229	0.69	71.5		58	40	49
7V,17	FLOOR					71.5				
						TRANSMISSION SUBTOTALS			40	49
SOLAR	ITEM		AREA	EXPOS-URE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows		N						
		doors								
	GLASS	windows		S						
		doors								
	GLASS	windows		E						
		doors								
	GLASS	windows		W						
		doors								
							SOLAR SUBTOTAL			
INTERNAL LOADS / ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts						CLG SENS LOAD	
	30	1.333	40		Incand.	Watts x 3.413 = BTUh			136	
					Fluor.	Watts x 4.1 = BTUh				
						Watts x 3.413 = BTUh				
							ELECT SUBTOTAL		136	
PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD	
EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12				
					EQUIPMENT SUBTOTALS					
INFILT	Tbl 13A & 13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG	2	Q_L = CFM x .69 x ΔG		71.5	22.6	40	55.2	49	
	Space HTG	2	Q_s = CFM x 1.08 x ΔT		71.5	22.6	40			154
	Door CLG				71.5	22.6	40			
	Door HTG				71.5	22.6	40			
					INFILTRATION SUBTOTALS			55.2	48.816	154.44
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration								55	225	204
									CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)									10	5
VENT	Tbl 14 ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG		71.5	22.6	40			
			Q_s = CFM x 1.08 x ΔT		71.5	22.6	40			
					VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load										
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =					0.02			55	225	204

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Room:	110 Spare Coset			Name:	Cody Knuth				
Cooling: Outside db	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db	2.5	*Inside db*	74	*Re: Tbl 1*					

EXTERNAL LOADS — TRANSMISSION

ITEM	EXPOS-URE	AREA	U	U X A	HTG ΔT	Aug TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
Wall	N				71.5				
	S	26.66	0.06	1.60	71.5	14	57	91	114
	E				71.5				
	W				71.5				
					71.5				
Glass					71.5		22.6		
					71.5		22.6		
Partitions					71.5		22.6		
					71.5		22.6		
Doors					71.5				
					71.5				
					71.5				
7S,7T ROOF/CEILING		28.89	0.0229	0.66	71.5	14	58	38	47
7V,17 FLOOR					71.5				
						TRANSMISSION SUBTOTALS		130	162

EXTERNAL LOADS — SOLAR

ITEM		AREA	EXPOS-URE	Tbl 2A,2B SF	Tbl 3 SHGF		BTUh COOLING LOAD
GLASS	windows		N				
	doors						
GLASS	windows		S				
	doors						
GLASS	windows		E				
	doors						
GLASS	windows		W				
	doors						
						SOLAR SUBTOTAL	

INTERNAL LOADS — ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
28.9	1.38	40		Incand.	Watts x 3.413 = BTUh	136
				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
					ELECT SUBTOTAL	136

INTERNAL LOADS — PEOPLE / EQUIP

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea				CLG LAT LOAD	CLG SENS LOAD
EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12		
					EQUIPMENT SUBTOTALS		

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG	1.926	Q_L = CFM x .69 x ΔG	71.5	22.6	40	53.1576	47	
Space HTG	1.926	Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			149
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
			INFILTRATION SUBTOTALS			53.1576	47.00981	148.7257
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration						53	313	310
							CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)							14	8

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
			VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load								
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =			0.03			53	313	310

	ITEM									
Project:	Burton Estate				Page:	11	of	26	Date:	
Room:	111 Spare Bedroom				Name:	Cody Knuth				
Cooling: Outside db		97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db		2.5	*Inside db*	74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS – TRANSMISSION	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	Aug TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N				71.5				
		S	87.75	0.06	5.27	71.5	14	57	300	376
		E				71.5				
		W	96	0.061	5.86	71.5	14	37	217	419
						71.5				
	Glass		12.25	0.5	6.13	71.5	14	22.6	138	438
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		150	0.0229	3.44	71.5	14	58	199	246
7V,17	FLOOR					71.5				
					TRANSMISSION SUBTOTALS				854	1479
EXTERNAL LOADS – SOLAR	ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows		N						
		doors								
	GLASS	windows	12.25	S	0.35	124			532	
		doors								
	GLASS	windows		E						
		doors								
	GLASS	windows		W						
		doors								
								SOLAR SUBTOTAL	532	
INTERNAL LOADS – ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts						CLG SENS LOAD	
	150	1.065	160		Incand.	Watts x 3.413 = BTUh			545	
					Fluor.	Watts x 4.1 = BTUh				
						Watts x 3.413 = BTUh				
								ELECT SUBTOTAL	545	
INTERNAL LOADS – PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD	
INTERNAL LOADS – EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12				
					EQUIPMENT SUBTOTALS					
INFILT	Tbl 13A & 13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG	10	Q_L = CFM x .69 x ΔG		71.5	22.6	40	276	244	
	Space HTG	10	Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			772
	Door CLG				71.5	22.6	40			
	Door HTG				71.5	22.6	40			
					INFILTRATION SUBTOTALS			276	244.08	772.2
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration								276	2175	2251
									CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)									101	60
VENT	Tbl 14 ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG		71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			
					VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load										
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =					0.20			276	2175	2251

Project:	Burton Estate			Page:	12	of	26	Date:	
Room:	112 Spare Bathroom			Name:	Cody Knuth				
Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains* 40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*				

EXTERNAL LOADS — TRANSMISSION

	ITEM	EXPOS-URE	AREA	U	U X A	HTG ΔT	July TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	N				71.5				
		S				71.5				
		E				71.5				
		W	44	0.061	2.68	71.5	17	79	212	192
						71.5				
	Glass					71.5		22.6		
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		68.75	0.0229	1.57	71.5	17	58	91	113
7V,17	FLOOR					71.5				
							TRANSMISSION SUBTOTALS		303	304

SOLAR

ITEM		AREA	EXPOS-URE	Tbl 2A,2B SF	Tbl 3 SHGF		
GLASS	windows		N				
	doors						
GLASS	windows		S				
	doors						
GLASS	windows		E				
	doors						
GLASS	windows		W				
	doors						
						SOLAR SUBTOTAL	

INTERNAL LOADS — ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
68.75	2.33	160		Incand.	Watts x 3.413 = BTUh	547
				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
					ELECT SUBTOTAL	547

PEOPLE

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea	CLG LAT LOAD	CLG SENS LOAD

EQUIP

EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12	CLG LAT LOAD	CLG SENS LOAD
				EQUIPMENT SUBTOTALS			

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG	4.583333	Q_L = CFM x .69 x ΔG	71.5	22.6	40	126.5	112	
Space HTG	4.583333	Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			354
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
			INFILTRATION SUBTOTALS			126.5	111.87	353.925

	CLG LAT	CLG SENS	HEATING
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration	127	962	658
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		45	17

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
			VENTILATION SUBTOTALS					

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load					
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.09		127	962	658

Project:	Burton Estate			Page:	13	of	26	Date:	
Room:	113 Den			Name:	Cody Knuth				
Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains* 40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*				

EXTERNAL LOADS — TRANSMISSION

	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	July TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	N	51.75	0.06	3.11	71.5	17	33	102	222
		S				71.5				
		E				71.5				
		W	96	0.061	5.86	71.5	17	79	463	419
						71.5				
	Glass		12.25	0.5	6.13	71.5	17	22.6	138	438
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		121	0.0229	2.77	71.5	17	58	161	198
7V,17	FLOOR					71.5				
							TRANSMISSION SUBTOTALS		864	1277

EXTERNAL LOADS — SOLAR

ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF		BTUh COOLING LOAD
GLASS	windows	12.25	N	0.35	32		137
	doors						
GLASS	windows		S				
	doors						
GLASS	windows		E				
	doors						
GLASS	windows		W				
	doors						
						SOLAR SUBTOTAL	137

INTERNAL LOADS — ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
121	0.66	80		Incand.	Watts x 3.413 = BTUh	273
				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
					ELECT SUBTOTAL	273

INTERNAL LOADS — PEOPLE

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea	CLG LAT LOAD	CLG SENS LOAD

INTERNAL LOADS — EQUIP

EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12	CLG LAT LOAD	CLG SENS LOAD
1		500	Computer				500
					EQUIPMENT SUBTOTALS		500

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG	8.066667	Q_L = CFM x .69 x ΔG	71.5	22.6	40	222.64	197	
Space HTG	8.066667	Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			623
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
			INFILTRATION SUBTOTALS			222.64	196.8912	622.908

	CLG LAT	CLG SENS	HEATING
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration	223	1971	1900
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		91	50

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
			VENTILATION SUBTOTALS					

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load				
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.18	223	1971	1900

Project:	Burton Estate		Page:	14	of	26	Date:	
Room:	114 Den Closet		Name:	Cody Knuth				

Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains* 40
Heating:	*Outside db*	2.5	*Inside db*	72	*Re: Tbl 1*				

EXTERNAL LOADS — TRANSMISSION

	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	N				69.5				
		S				69.5				
		E				69.5				
		W				69.5				
						69.5				
	Glass					69.5		22.6		
						69.5		22.6		
	Partitions					69.5		22.6		
						69.5		22.6		
	Doors					69.5				
						69.5				
						69.5				
7S,7T	ROOF/CEILING		21	0.0229	0.48	69.5		58	28	33
7V,17	FLOOR					69.5				
							TRANSMISSION SUBTOTALS		28	33

SOLAR

ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF		
GLASS	windows		N				
	doors						
GLASS	windows		S				
	doors						
GLASS	windows		E				
	doors						
GLASS	windows		W				
	doors						
						SOLAR SUBTOTAL	

INTERNAL LOADS — ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
21	1.9	40		Incand.	Watts x 3.413 = BTUh	136
				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
					ELECT SUBTOTAL	136

PEOPLE / EQUIP

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea				CLG LAT LOAD	CLG SENS LOAD
EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12		
				EQUIPMENT SUBTOTALS			

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG	1.4	Q_L = CFM x .69 x ΔG	69.5	22.6	40	38.64	34	
Space HTG	1.4	Q_S = CFM x 1.08 x ΔT	69.5	22.6	40			105
Door CLG			69.5	22.6	40			
Door HTG			69.5	22.6	40			
			INFILTRATION SUBTOTALS			38.64	34.1712	105.084

	CLG LAT	CLG SENS	HEATING
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration	39	198	139
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		9	4

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	69.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	69.5	22.6	40			
			VENTILATION SUBTOTALS					

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load					
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.02		39	198	139

Project:	Burton Estate				Page:	15	of	26	Date:	
Room:	115 Corridor				Name:	Cody Knuth				
Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*			Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
EXTERNAL LOADS – TRANSMISSION	ITEM	EXPOS-URE	AREA	U	U X A	HTG ΔT	TIME			
	Wall	N				71.5				
		S				71.5				
		E				71.5				
		W				71.5				
						71.5				
	Glass					71.5		22.6		
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		70.83	0.0229	1.62	71.5		58	94	116
7V,17	FLOOR					71.5				
						TRANSMISSION SUBTOTALS			94	116
EXTERNAL LOADS – SOLAR	ITEM		AREA	EXPOS-URE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows		N						
		doors								
	GLASS	windows		S						
		doors								
	GLASS	windows		E						
		doors								
	GLASS	windows		W						
		doors								
							SOLAR SUBTOTAL			
INTERNAL LOADS – ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts						CLG SENS LOAD	
	70.83	1.13	80		Incand.	Watts x 3.413 = BTUh			273	
					Fluor.	Watts x 4.1 = BTUh				
						Watts x 3.413 = BTUh				
							ELECT SUBTOTAL		273	
INTERNAL LOADS – PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD	
INTERNAL LOADS – EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12				
					EQUIPMENT SUBTOTALS					
INFILT	Tbl 13A & 13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG	4.722	Q_L = CFM x .69 x ΔG		71.5	22.6	40	130.3272	115	
	Space HTG	4.722	Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			365
	Door CLG				71.5	22.6	40			
	Door HTG				71.5	22.6	40			
					INFILTRATION SUBTOTALS			130.3272	115.2546	364.6328
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration								130	483	481
									CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)									22	13
VENT	Tbl 14 ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG		71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			
					VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load										
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =					0.05			130	483	481

Project:	Burton Estate			Page:	16	of	26	Date:	
Room:	116 Stair			Name:	Cody Knuth				
Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains* 40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*				

EXTERNAL LOADS – TRANSMISSION

	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	N				71.5				
		S				71.5				
		E				71.5				
		W				71.5				
						71.5				
	Glass					71.5		22.6		
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		49.8	0.0229	1.14	71.5		58	66	82
7V,17	FLOOR					71.5				
							TRANSMISSION SUBTOTALS		66	82

EXTERNAL LOADS – SOLAR

ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF		COOLING LOAD
GLASS	windows		N				
	doors						
GLASS	windows		S				
	doors						
GLASS	windows		E				
	doors						
GLASS	windows		W				
	doors						
						SOLAR SUBTOTAL	

INTERNAL LOADS – ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
49.8	0.8	40		Incand.	Watts x 3.413 = BTUh	136
				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
					ELECT SUBTOTAL	136

INTERNAL LOADS – PEOPLE / EQUIP

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea				CLG LAT LOAD	CLG SENS LOAD
EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12		
				EQUIPMENT SUBTOTALS			

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG	3.32	Q_L = CFM x .69 x ΔG	71.5	22.6	40	91.632	81	
Space HTG	3.32	Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			256
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
			INFILTRATION SUBTOTALS			91.632	81.03456	256.3704
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration						92	283	338
							CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)							13	9

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
			VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load								
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =			0.03			92	283	338

Project:	Burton Residence	Page:	17	of	26	Date:	
Room:	001 Corridor	Name:	Cody Knuth				

Cooling: Outside db	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains* 40
Heating: Outside db	2.5	*Inside db*	74	*Re: Tbl 1*				

EXTERNAL LOADS

TRANSMISSION

ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
Wall	N					71.5				
	S					71.5				
	E					71.5				
	W					71.5				
						71.5				
Glass						71.5		22.6		
						71.5		22.6		
Partitions						71.5		22.6		
						71.5		22.6		
Doors						71.5				
						71.5				
						71.5				
7S,7T ROOF/CEILING						71.5				
7V,17 FLOOR		33.25	1.7			71.5				57
						TRANSMISSION SUBTOTALS				57

SOLAR

ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF			BTUh COOLING LOAD
GLASS	windows			N					
	doors								
GLASS	windows			S					
	doors								
GLASS	windows			E					
	doors								
GLASS	windows			W					
	doors								
							SOLAR SUBTOTAL		

INTERNAL LOADS

ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
33.25	1.2	40		Incand.	Watts x 3.413 = BTUh	136
				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
					ELECT SUBTOTAL	136

PEOPLE / EQUIP

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD
EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12		
					EQUIPMENT SUBTOTALS			

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
Space HTG		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
		INFILTRATION SUBTOTALS						

Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration		136	57
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		6	1

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
		VENTILATION SUBTOTALS						

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads				
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.01		136	57

Project:	Burton Estate			Page:	18	of	26	Date:	
Room:	002 Spare Closet			Name:	Cody Knuth				
Cooling: Outside db	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db	2.5	*Inside db*	74	*Re: Tbl 1*					

EXTERNAL LOADS – TRANSMISSION

ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	Aug. TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
Wall	S	14		0.3063	4.29	71.5	14	25	107	307
	S	14	7.5			71.5				105
	S					71.5				
	W					71.5				
						71.5				
Glass						71.5		22.6		
						71.5		22.6		
Partitions						71.5		22.6		
						71.5		22.6		
Doors						71.5				
						71.5				
						71.5				
7S,7T ROOF/CEILING						71.5				
7V,17 FLOOR		22.15	1.7			71.5				38
TRANSMISSION SUBTOTALS									107	449

EXTERNAL LOADS – SOLAR

ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF	
GLASS	windows		N			
	doors					
GLASS	windows		S			
	doors					
GLASS	windows		E			
	doors					
GLASS	windows		W			
	doors					
SOLAR SUBTOTAL						

INTERNAL LOADS – ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts			CLG SENS LOAD
22.15	1.8	40	Incand.	Watts x 3.413 = BTUh	136
			Fluor.	Watts x 4.1 = BTUh	
				Watts x 3.413 = BTUh	
ELECT SUBTOTAL					136

INTERNAL LOADS – PEOPLE / EQUIP

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea				CLG LAT LOAD	CLG SENS LOAD
EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12		
EQUIPMENT SUBTOTALS							

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
Space HTG		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
INFILTRATION SUBTOTALS								

Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration		243	449
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		11	12

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
VENTILATION SUBTOTALS								

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads				
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.02		243	449

Project:	Burton Estate		Page:	19	of	26	Date:	
Room:	003 Spare Bedroom		Name:	Cody Knuth				
Cooling: Outside db	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains* 40
Heating: Outside db	2.5	*Inside db*	74	*Re: Tbl 1*				

EXTERNAL LOADS — TRANSMISSION

ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
Wall	S	42.25		0.3063	12.94	71.5	17	39	505	925
	S	42.25	7.5			71.5				317
	W	56		0.3063	17.15	71.5	17	56	961	1226
	W	56	7.5			71.5				420
						71.5				
Glass		3.75		0.81	3.04	71.5	17	22.6	69	217
						71.5		22.6		
Partitions						71.5		22.6		
						71.5		22.6		
Doors						71.5				
						71.5				
						71.5				
7S,7T ROOF/CEILING						71.5				
7V,17 FLOOR		181.25	1.7			71.5				308
TRANSMISSION SUBTOTALS									1534	3414

SOLAR

ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF	BTUh COOLING LOAD
GLASS	windows			N			
	doors						
GLASS	windows	3.75		S	0.35	124	163
	doors						
GLASS	windows			E			
	doors						
GLASS	windows			W			
	doors						
SOLAR SUBTOTAL							163

INTERNAL LOADS — ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
181.25	0.441	80		Incand.	Watts x 3.413 = BTUh	273
				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
ELECT SUBTOTAL						273

PEOPLE / EQUIP

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea				CLG LAT LOAD	CLG SENS LOAD
1	200	250				200	250
EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12		
EQUIPMENT SUBTOTALS						200	250

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
Space HTG		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
INFILTRATION SUBTOTALS								
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration						200	2219	3414
							CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)							103	90

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
VENTILATION SUBTOTALS								
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads								
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =			0.20			200	2219	3414

Project:	Burton Estate	Page:	20	of	26	Date:	
Room:	004 Spare Bathroom	Name:	Cody Knuth				

Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*					

EXTERNAL LOADS

TRANSMISSION

	ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	W	12.66		0.3063	3.88	71.5	17	56	217	277
		W	12.66	7.5			71.5				95
		W					71.5				
		W					71.5				
							71.5				
	Glass						71.5		22.6		
							71.5		22.6		
	Partitions						71.5		22.6		
							71.5		22.6		
	Doors						71.5				
							71.5				
							71.5				
7S,7T	ROOF/CEILING						71.5				
7V,17	FLOOR		52.5	1.7			71.5				89
								TRANSMISSION SUBTOTALS		217	461

SOLAR

ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF	
GLASS	windows			N			
	doors						
GLASS	windows			S			
	doors						
GLASS	windows			E			
	doors						
GLASS	windows			W			
	doors						
						SOLAR SUBTOTAL	

INTERNAL LOADS

ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts					CLG SENS LOAD
52.5	3.05	160			Incand.	Watts x 3.413 = BTUh	547
					Fluor.	Watts x 4.1 = BTUh	
						Watts x 3.413 = BTUh	
						ELECT SUBTOTAL	547

PEOPLE

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea	CLG LAT LOAD	CLG SENS LOAD

EQUIP

EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12		
						EQUIPMENT SUBTOTALS		

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
Space HTG		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
			INFILTRATION SUBTOTALS					

Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration		764	461
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		35	12

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
			VENTILATION SUBTOTALS					

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads				
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.06		764	461

Project:	Burton Estate					Page:	21	of	26	Date:	
Room:	005 Closet					Name:	Cody Knuth				
Cooling: Outside db		97.6	*wb*		75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db		2.5	*Inside db*		74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS / TRANSMISSION	ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N					71.5				
		S					71.5				
		E					71.5				
		W					71.5				
							71.5				
	Glass						71.5		22.6		
							71.5		22.6		
	Partitions						71.5		22.6		
							71.5		22.6		
	Doors						71.5				
							71.5				
							71.5				
7S,7T	ROOF/CEILING						71.5				
7V,17	FLOOR		7.77	1.7			71.5				13
	TRANSMISSION SUBTOTALS										13
SOLAR	ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows			N						
		doors									
	GLASS	windows			S						
		doors									
	GLASS	windows			E						
		doors									
	GLASS	windows			W						
		doors									
	SOLAR SUBTOTAL										
INTERNAL LOADS / ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts							CLG SENS LOAD	
	7.72	5.16	40			Incand.	Watts x 3.413 = BTUh			136	
						Fluor.	Watts x 4.1 = BTUh				
							Watts x 3.413 = BTUh				
	ELECT SUBTOTAL									136	
PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea						CLG LAT LOAD	CLG SENS LOAD	
EQUIP	EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12				
	EQUIPMENT SUBTOTALS										
INFILT	Tbl 13A & 13B ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG		Q_L = CFM x .69 x ΔG			71.5	22.6	40			
	Space HTG		Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
	Door CLG					71.5	22.6	40			
	Door HTG					71.5	22.6	40			
	INFILTRATION SUBTOTALS										
	Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration									136	13
										CLG CFM	HTG CFM
	Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)									6	0
VENT	Tbl 14 ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG			71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
	VENTILATION SUBTOTALS										
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads											
	Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =					0.01				136	13

Project:	Burton Estate				Page:	22	of	26	Date:	
Room:	006 Lounge				Name:	Cody Knuth				
Cooling: Outside db	97.6	*wb*		75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db	2.5	*Inside db*		74	*Re: Tbl 1*					

EXTERNAL LOADS – TRANSMISSION

ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
Wall	N	32.66		0.3063	10.00	71.5	17	20	200	715
	N	32.66	7.5			71.5				245
	W	50		0.3063	15.32	71.5	17	56	858	1095
	W	50	7.5			71.5				375
Glass						71.5		22.6		
						71.5		22.6		
Partitions						71.5		22.6		
						71.5		22.6		
Doors						71.5				
						71.5				
						71.5				
7S,7T ROOF/CEILING						71.5				
7V,17 FLOOR		205.25	1.7			71.5				349
TRANSMISSION SUBTOTALS									1058	2779

EXTERNAL LOADS – SOLAR

ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF	
GLASS	windows			N			
	doors						
GLASS	windows			S			
	doors						
GLASS	windows			E			
	doors						
GLASS	windows			W			
	doors						
SOLAR SUBTOTAL							

INTERNAL LOADS – ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts					CLG SENS LOAD
					Incand.	Watts x 3.413 = BTUh	
205.25	0.779	160			Fluor.	Watts x 4.1 = BTUh	656
						Watts x 3.413 = BTUh	
ELECT SUBTOTAL							656

INTERNAL LOADS – PEOPLE / EQUIP

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD
EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12		
EQUIPMENT SUBTOTALS								

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
Space HTG		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
INFILTRATION SUBTOTALS								

Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration		1713	2779
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		79	74

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
VENTILATION SUBTOTALS								

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads						
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.14				1713	2779

Project:	Burton Estate					Page:	23	of	26	Date:	
Room:	007 Living Room					Name:	Cody Knuth				
Cooling:	*Outside db*	97.6	*wb*		75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating:	*Outside db*	2.5	*Inside db*		74	*Re: Tbl 1*					

EXTERNAL LOADS – TRANSMISSION	ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	E	106.25		0.3063	32.54	71.5	10	23	749	2327
		E	106.25	7.5			71.5				797
		W	55.34		0.3063	16.95	71.5	10	20	339	1212
		W	55.34	7.5			71.5				415
							71.5				
	Glass		3.75		0.81	3.04	71.5	10	22.6	69	217
							71.5		22.6		
	Partitions						71.5		22.6		
							71.5		22.6		
	Doors						71.5				
							71.5				
							71.5				
7S,7T	ROOF/CEILING						71.5				
7V,17	FLOOR		467.54	1.7			71.5				795
							TRANSMISSION SUBTOTALS			1156	5763

EXTERNAL LOADS – SOLAR	ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF	BTUh COOLING LOAD
	GLASS	windows			N			
		doors						
	GLASS	windows			S			
		doors						
	GLASS	windows	3.75		E	0.35	164	215
		doors						
	GLASS	windows			W			
		doors						
							SOLAR SUBTOTAL	215

INTERNAL LOADS – ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts					CLG SENS LOAD
						Incand.	Watts x 3.413 = BTUh	
	467.54	0.684	320			Fluor.	Watts x 4.1 = BTUh	1311
							Watts x 3.413 = BTUh	
							ELECT SUBTOTAL	1311

INTERNAL LOADS – PEOPLE / EQUIP	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD
	EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12		
						EQUIPMENT SUBTOTALS			

INFILT	Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
	Space HTG		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
	Door CLG			71.5	22.6	40			
	Door HTG			71.5	22.6	40			
			INFILTRATION SUBTOTALS						

Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration		2683	5763
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		124	152

VENT	Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG	71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
			VENTILATION SUBTOTALS						

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads				
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.22		2683	5763

Project:		Burton Estate					Page:	24	of	26	Date:	
Room:		008 Storage					Name:	Cody Knuth				
Cooling: Outside db			97.6	*wb*		75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db			2.5	*Inside db*		74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS	TRANSMISSION	ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
		Wall	N	26.66		0.3063	8.17	71.5	18	21	171	584
			N	26.66	7.5			71.5				200
			S	16.334		0.3063	5.00	71.5	18	22	110	358
			S	16.334	7.5			71.5				123
								71.5				
		Glass						71.5		22.6		
								71.5		22.6		
		Partitions						71.5		22.6		
								71.5		22.6		
		Doors						71.5				
								71.5				
								71.5				
	7S,7T	ROOF/CEILING						71.5				
	7V,17	FLOOR		245.75	1.7			71.5				418
							TRANSMISSION SUBTOTALS				282	1682
	SOLAR	ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
		GLASS	windows			N						
			doors									
		GLASS	windows			S						
			doors									
		GLASS	windows			E						
			doors									
		GLASS	windows			W						
			doors									
										SOLAR SUBTOTAL		
INTERNAL LOADS	ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts							CLG SENS LOAD	
							Incand.	Watts x 3.413 = BTUh				
		245.75	0.651	160			Fluor.	Watts x 4.1 = BTUh			656	
								Watts x 3.413 = BTUh				
										ELECT SUBTOTAL	656	
	PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea						CLG LAT LOAD	CLG SENS LOAD	
	EQUIP	EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12				
							EQUIPMENT SUBTOTALS					
INFILT		Tbl 13A & 13B ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Space CLG		Q_L = CFM x .69 x ΔG			71.5	22.6	40			
		Space HTG		Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
		Door CLG					71.5	22.6	40			
		Door HTG					71.5	22.6	40			
							INFILTRATION SUBTOTALS					
		Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration									937	1682
											CLG CFM	HTG CFM
		Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)									43	44
VENT		Tbl 14 ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
				Q_L = CFM x .69 x ΔG			71.5	22.6	40			
				Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
							VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads												
		Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =					0.08				937	1682

Project:	Burton Estate					Page:	25	of	26	Date:	
Room:	009 Fitness					Name:	Cody Knuth				
Cooling: Outside db		97.6	*wb*		75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db		2.5	*Inside db*		74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS – TRANSMISSION	ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N	47.33		0.3063	14.50	71.5	10	14	203	1037
		N	47.33	7.5			71.5				355
		E	54		0.3063	16.54	71.5	10	23	380	1183
		E	54	7.5			71.5				405
							71.5				
	Glass						71.5		22.6		
							71.5		22.6		
	Partitions						71.5		22.6		
							71.5		22.6		
	Doors						71.5				
							71.5				
							71.5				
7S,7T	ROOF/CEILING						71.5				
7V,17	FLOOR		180.84	1.7			71.5				307
						TRANSMISSION SUBTOTALS				583	3287
EXTERNAL LOADS – SOLAR	ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows			N						
		doors									
	GLASS	windows			S						
		doors									
	GLASS	windows			E						
		doors									
	GLASS	windows			W						
		doors									
								SOLAR SUBTOTAL			
INTERNAL LOADS – ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts							CLG SENS LOAD	
						Incand.	Watts x 3.413 = BTUh				
	180.84	0.885	160			Fluor.	Watts x 4.1 = BTUh			656	
							Watts x 3.413 = BTUh				
								ELECT SUBTOTAL		656	
INTERNAL LOADS – PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea						CLG LAT LOAD	CLG SENS LOAD	
INTERNAL LOADS – EQUIP	EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12				
						EQUIPMENT SUBTOTALS					
INFILT	Tbl 13A & 13B ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG		Q_L = CFM x .69 x ΔG			71.5	22.6	40			
	Space HTG		Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
	Door CLG					71.5	22.6	40			
	Door HTG					71.5	22.6	40			
						INFILTRATION SUBTOTALS					
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration										1240	3287
										CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)										57	87
VENT	Tbl 14 ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG			71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
						VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads											
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =						0.10				1240	3287

Project:	Burton Estate			Page:	26	of	26	Date:	
Room:	010 Laundry			Name:	Cody Knuth				
Cooling: Outside db	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db	2.5	*Inside db*	74	*Re: Tbl 1*					

		ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
EXTERNAL LOADS	TRANSMISSION	Wall	S	58		0.3063	17.77	71.5	10	17	302	1270
			S	58	7.5			71.5				435
			E	58.92		0.3063	18.05	71.5	10	23	415	1290
			E	58.92	7.5			71.5				442
								71.5				
		Glass		3.75		0.81	3.04	71.5	10	22.6	69	217
								71.5		22.6		
		Partitions						71.5		22.6		
								71.5		22.6		
		Doors						71.5				
								71.5				
								71.5				
	7S,7T	ROOF/CEILING						71.5				
	7V,17	FLOOR		227	1.7			71.5				386
		TRANSMISSION SUBTOTALS									786	4041

		ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF			BTUh COOLING LOAD
EXTERNAL LOADS	SOLAR	GLASS	windows			N					
			doors								
		GLASS	windows			S					
			doors								
		GLASS	windows	3.75		E	0.35	164			215
			doors								
		GLASS	windows			W					
			doors								
		SOLAR SUBTOTAL									215

		LIGHTS / POWER	W/Fixt or W/SF	Total Watts					CLG SENS LOAD
INTERNAL LOADS	ELECT	227	0.705	160			Incand.	Watts x 3.413 = BTUh	546
							Fluor.	Watts x 4.1 = BTUh	
								Watts x 3.413 = BTUh	
		ELECT SUBTOTAL							546

		Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD
INTERNAL LOADS	PEOPLE									
	EQUIP	EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12		
		1		4000						4000
		EQUIPMENT SUBTOTALS								4000

	Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
INFILT	Space CLG		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
	Space HTG		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
	Door CLG			71.5	22.6	40			
	Door HTG			71.5	22.6	40			
	INFILTRATION SUBTOTALS								
	Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration							5547	4041
								CLG CFM	HTG CFM
	Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)							257	107

	Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
VENT			Q_L = CFM x .69 x ΔG	71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
	VENTILATION SUBTOTALS								
	Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads								
	Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =			0.46				5547	4041

Table A-2 Room Load Calculation Workbook with Diversified LPD's

Project:	Burton Residence				Page:		of	26	Date:	
Room:	101 Vestibule				Name:	Cody Knuth				
Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS – TRANSMISSION	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N				71.5				
		S				71.5				
		E				71.5				
		W	46	0.06	2.76	71.5	17	79	218	197
						71.5				
	Glass		24	0.79	18.96	71.5	17	22.6	428	1356
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors		42	0.365	15.33	71.5	17	22.6	346	1096
						71.5				
						71.5				
7S,7T	ROOF/CEILING		104	0.0229	2.38	71.5	17	58	138	170
7V,17	FLOOR					71.5				
						TRANSMISSION SUBTOTALS			1131	2819
SOLAR	ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows		N						
		doors								
	GLASS	windows		S						
		doors								
	GLASS	windows		E						
		doors								
	GLASS	windows	24	W	0.35	116			974	
		doors								
							SOLAR SUBTOTAL		974	
INTERNAL LOADS – ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts						CLG SENS LOAD	
	104				Incand.	Watts x 3.413 = BTUh				
					Fluor.	Watts x 4.1 = BTUh				
						Watts x 3.413 = BTUh				
							ELECT SUBTOTAL			
PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD	
EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12				
					EQUIPMENT SUBTOTALS					
INFILT	Tbl 13A & 13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG	6.933333	Q_L = CFM x .69 x ΔG		71.5	22.6	40	191.36	169	
	Space HTG	6.933333	Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			535
	Door CLG				71.5	22.6	40			
	Door HTG				71.5	22.6	40			
					INFILTRATION SUBTOTALS			191.36	169.2288	535.392
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration								191	2275	3355
									CLG CFM	HTG CFM
	Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)								105	89
VENT	Tbl 14 ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG		71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			
					VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load										
	Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =				0.21			191	2275	3355

Project:	Burton Estate			Page:		of	26	Date:	
Room:	102 Kitchen			Name:	Cody Knuth				
Cooling: Outside db	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db	2.5	*Inside db*	74	*Re: Tbl 1*					

EXTERNAL LOADS – TRANSMISSION

	ITEM	EXPOS-URE	AREA	U	U X A	HTG ΔT	July TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	N	73	0.06	4.38	71.5	18	33	145	313
		S	51.75	0.061	3.16	71.5	18	37	117	226
		E				71.5				
		W				71.5				
						71.5				
	Glass		19.25	0.5	9.63	71.5	18	22.6	218	688
						71.5		22.6		
	Partitions		100	0.06	6.00	37	18	22.6		222
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		225	0.0229	5.15	71.5	18	58	299	368
7V,17	FLOOR					71.5				
								TRANSMISSION SUBTOTALS	778	1817

EXTERNAL LOADS – SOLAR

ITEM		AREA	EXPOS-URE	Tbl 2A,2B SF	Tbl 3 SHGF		CLG LOAD
GLASS	windows	7	N	0.35	32		78
	doors						
GLASS	windows	12.25	S	0.35	124		532
	doors						
GLASS	windows		E				
	doors						
GLASS	windows		W				
	doors						
						SOLAR SUBTOTAL	610

INTERNAL LOADS – ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
225	0.119	27		Incand.	Watts x 3.413 = BTUh	91
225	0.119	27		Fluor.	Watts x 4.1 = BTUh	110
					Watts x 3.413 = BTUh	
					ELECT SUBTOTAL	201

INTERNAL LOADS – PEOPLE

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea	CLG LAT LOAD	CLG SENS LOAD

INTERNAL LOADS – EQUIP

EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12	CLG LAT LOAD	CLG SENS LOAD
1		3200	Refrig, MW & Range				3200
1	3010	1040	Dishwasher			3010	1040
					EQUIPMENT SUBTOTALS	3010	4240

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG	15	Q_L = CFM x .69 x ΔG	71.5	22.6	40	414	366	
Space HTG	15	Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			1158
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
		INFILTRATION SUBTOTALS				414	366.12	1158.3

	CLG LAT	CLG SENS	HEATING
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration	3424	6195	2976
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		287	79

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
		VENTILATION SUBTOTALS						

			CLG LAT	CLG SENS	HEATING
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load					
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.80		3424	6195	2976

Project:	Burton Estate			Page:		of	26	Date:	
Room:	103 Pantry			Name:	Cody Knuth				
Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains* 40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*				

EXTERNAL LOADS — TRANSMISSION

	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	N				71.5				
		S				71.5				
		E				71.5				
		W				71.5				
						71.5				
	Glass					71.5		22.6		
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		12	0.0229	0.27	71.5		58	16	20
7V,17	FLOOR					71.5				
								TRANSMISSION SUBTOTALS	16	20

EXTERNAL LOADS — SOLAR

ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF		BTUh COOLING LOAD
GLASS	windows		N				
	doors						
GLASS	windows		S				
	doors						
GLASS	windows		E				
	doors						
GLASS	windows		W				
	doors						
						SOLAR SUBTOTAL	

INTERNAL LOADS — ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
12				Incand.	Watts x 3.413 = BTUh	
				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
					ELECT SUBTOTAL	

INTERNAL LOADS — PEOPLE

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea	CLG LAT LOAD	CLG SENS LOAD

INTERNAL LOADS — EQUIP

EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12	CLG LAT LOAD	CLG SENS LOAD
					EQUIPMENT SUBTOTALS		

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG	0.8	Q_L = CFM x .69 x ΔG	71.5	22.6	40	22.08	20	
Space HTG	0.8	Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			62
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
				INFILTRATION SUBTOTALS		22.08	19.5264	61.776

	CLG LAT	CLG SENS	HEATING
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration	22	35	81
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		2	2

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
				VENTILATION SUBTOTALS				

		CLG LAT	CLG SENS	HEATING
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load				
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.00	22	35	81

Project:	Burton Estate				Page:		of	26	Date:	
Room:	104 Sun Room				Name:	Cody Knuth				
Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS – TRANSMISSION	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N	72	0.06	4.32	71.5	17	33	143	309
		S				71.5				
		E	56	0.06	3.36	71.5	17	34	114	240
		W	56	0.06	3.36	71.5	17	79	265	240
						71.5				
	Glass		105	0.5	52.50	71.5	17	22.6	1187	3754
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors		17.62	0.365	6.43	71.5	17	22.6	145	460
						71.5				
						71.5				
7S,7T	ROOF/CEILING		170.333	0.0229	3.90	71.5	17	58	226	279
7V,17	FLOOR					71.5				
	TRANSMISSION SUBTOTALS								2080	5282
EXTERNAL LOADS – SOLAR	ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF			BTUh COOLING LOAD	BTUh HEATING LOAD
	GLASS	windows	40	N	0.35	32			448	
		doors								
	GLASS	windows		S						
		doors								
	GLASS	windows	32.5	E	0.35	164			1866	
		doors								
	GLASS	windows	32.5	W	0.35	156			1775	
		doors								
	SOLAR SUBTOTAL								4088	
INTERNAL LOADS – ELECT	LIGHTS / POWER	or W/SF	Total Watts						CLG SENS LOAD	
	170.33	0.033	6		Incand.	Watts x 3.413 = BTUh			19	
					Fluor.	Watts x 4.1 = BTUh				
						Watts x 3.413 = BTUh				
	ELECT SUBTOTAL								19	
INTERNAL LOADS – PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD	
INTERNAL LOADS – EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12				
	EQUIPMENT SUBTOTALS									
INFILT	Tbl 13A & 13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG	11.35553	Q_L = CFM x .69 x ΔG		71.5	22.6	40	313.4127	277	
	Space HTG	11.35553	Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			877
	Door CLG				71.5	22.6	40			
	Door HTG				71.5	22.6	40			
	INFILTRATION SUBTOTALS							313.4127	277.1659	876.874
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration								313	6465	6159
									CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)									299	163
VENT	Tbl 14 ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG		71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			
	VENTILATION SUBTOTALS									
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load										
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =					0.56			313	6465	6159

Project:	Burton Estate			Page:		of	26	Date:	
Room:	105 Dining Room			Name:	Cody Knuth				
Cooling: Outside db	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db	2.5	*Inside db*	74	*Re: Tbl 1*					

EXTERNAL LOADS — TRANSMISSION

	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	July TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	N	8	0.06	0.48	71.5	10	20	10	34
		S				71.5				
		E	64.667	0.06	3.88	71.5	10	62	241	277
		W				71.5				
						71.5				
	Glass		36.667	0.5	18.33	71.5	10	22.6	414	1311
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		158.338	0.0229	3.63	71.5	10	58	210	259
7V,17	FLOOR					71.5				
							TRANSMISSION SUBTOTALS		875	1882

EXTERNAL LOADS — SOLAR

ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF		BTUh COOLING LOAD
GLASS	windows		N				
	doors						
GLASS	windows		S				
	doors						
GLASS	windows	64.667	E	0.35	164		3712
	doors						
GLASS	windows		W				
	doors						
						SOLAR SUBTOTAL	3712

INTERNAL LOADS — ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
158.34	0.007	1		Incand.	Watts x 3.413 = BTUh	4
				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
					ELECT SUBTOTAL	4

INTERNAL LOADS — PEOPLE / EQUIP

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea				CLG LAT LOAD	CLG SENS LOAD
EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12		
				EQUIPMENT SUBTOTALS			

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG	10.55587	Q_L = CFM x .69 x ΔG	71.5	22.6	40	291.3419	258	
Space HTG	10.55587	Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			815
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
			INFILTRATION SUBTOTALS			291.3419	257.6476	815.124

	CLG LAT	CLG SENS	HEATING
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration	291	4848	2697
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		224	71

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
			VENTILATION SUBTOTALS					

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load				
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.43	291	4848	2697

Project:		Burton Estate				Page:		of	26	Date:	
Room:		106 Living Room				Name:	Cody Knuth				
Cooling:		*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating:		*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS	TRANSMISSION	ITEM	EXPOS-URE	AREA	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
		Wall	N				71.5				
			S				71.5				
			E	151.943	0.06	9.12	71.5	10	62	565	652
			W				71.5				
							71.5				
		Glass		34.7	0.5	17.35	71.5	10	22.6	392	1241
							71.5		22.6		
		Partitions					71.5		22.6		
							71.5		22.6		
		Doors					71.5				
							71.5				
							71.5				
	7S,7T	ROOF/CEILING		342.32	0.0229	7.84	71.5	10	58	455	560
	7V,17	FLOOR					71.5				
							TRANSMISSION SUBTOTALS			1412	2453
	SOLAR	ITEM		AREA	EXPOS-URE	Tbl 2A,2B SF	Tbl 3 SHGF				
		GLASS	windows		N						
			doors								
		GLASS	windows		S						
			doors								
		GLASS	windows	34.7	E	0.35	164			1992	
			doors								
		GLASS	windows		W						
			doors								
								SOLAR SUBTOTAL		1992	
INTERNAL LOADS	ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts						CLG SENS LOAD	
		342.32	0.006	2		Incand.	Watts x 3.413 = BTUh			7	
						Fluor.	Watts x 4.1 = BTUh				
							Watts x 3.413 = BTUh				
								ELECT SUBTOTAL		7	
	PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD	
	EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12				
						EQUIPMENT SUBTOTALS					
INFILT		Tbl 13A & 13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Space CLG	22.82133	Q_L = CFM x .69 x ΔG		71.5	22.6	40	629.8688	557	
		Space HTG	22.82133	Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			1762
		Door CLG				71.5	22.6	40			
		Door HTG				71.5	22.6	40			
						INFILTRATION SUBTOTALS			629.8688	557.0231	1762.263
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration									630	3968	4215
										CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)										184	112
VENT		Tbl 14 ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
				Q_L = CFM x .69 x ΔG		71.5	22.6	40			
				Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			
						VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load											
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =						0.38			630	3968	4215

Project:	Burton Estate				Page:		of	26	Date:	
Room:	107 Master Bathroom				Name:	Cody Knuth				
Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS – TRANSMISSION	ITEM	EXPOS-URE	AREA	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N				71.5				
		S				71.5				
		E	63.64	0.06	3.82	71.5	10	62	237	273
		W				71.5				
						71.5				
	Glass		3	0.5	1.50	71.5	10	22.6	34	107
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		52.275	0.0229	1.20	71.5	10	58	69	86
7V,17	FLOOR					71.5				
						TRANSMISSION SUBTOTALS			340	466
EXTERNAL LOADS – SOLAR	ITEM		AREA	EXPOS-URE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows		N						
		doors								
	GLASS	windows		S						
		doors								
	GLASS	windows	3	E	0.35	164			172	
		doors								
	GLASS	windows		W						
		doors								
							SOLAR SUBTOTAL		172	
INTERNAL LOADS – ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts						CLG SENS LOAD	
	52.275	0.159	8		Incand.	Watts x 3.413 = BTUh			28	
					Fluor.	Watts x 4.1 = BTUh				
						Watts x 3.413 = BTUh				
							ELECT SUBTOTAL		28	
INTERNAL LOADS – PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD	
	2	200	250					400	500	
INTERNAL LOADS – EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12				
					EQUIPMENT SUBTOTALS			400	500	
INFILT	Tbl 13A & 13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG	3.485	Q_L = CFM x .69 x ΔG		71.5	22.6	40	96.186	85	
	Space HTG	3.485	Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			269
	Door CLG				71.5	22.6	40			
	Door HTG				71.5	22.6	40			
					INFILTRATION SUBTOTALS			96.186	85.06188	269.1117
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration								496	1126	735
									CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)									52	19
VENT	Tbl 14 ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG		71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			
					VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load										
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =					0.14			496	1126	735

Project:	Burton Estate			Page:		of	26	Date:	
Room:	108 Master Bedroom			Name:	Cody Knuth				
Cooling: Outside db	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db	2.5	*Inside db*	74	*Re: Tbl 1*					

EXTERNAL LOADS — TRANSMISSION

	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	Aug TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	N				71.5				
		S	114.664	0.06	6.88	71.5	14	57	392	492
		E	83.75	0.06	5.03	71.5	14	38	191	359
		W				71.5				
						71.5				
	Glass		12.25	0.5	6.13	71.5	14	22.6	138	438
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		172	0.0229	3.94	71.5	14	58	228	282
7V,17	FLOOR					71.5				
								TRANSMISSION SUBTOTALS	950	1571

SOLAR

ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF		BTUh COOLING LOAD
GLASS	windows		N				
	doors						
GLASS	windows		S				
	doors						
GLASS	windows	12.25	E	0.35	164		703
	doors						
GLASS	windows		W				
	doors						
						SOLAR SUBTOTAL	703

INTERNAL LOADS — ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
172	0.019	3		Incand.	Watts x 3.413 = BTUh	11
				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
					ELECT SUBTOTAL	11

PEOPLE / EQUIP

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea				CLG LAT LOAD	CLG SENS LOAD
1	200	250				200	250
EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12		
					EQUIPMENT SUBTOTALS	200	250

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG	11.46667	Q_L = CFM x .69 x ΔG	71.5	22.6	40	316.48	280	
Space HTG	11.46667	Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			885
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
				INFILTRATION SUBTOTALS		316.48	279.8784	885.456

	CLG LAT	CLG SENS	HEATING
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration	516	2194	2456
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		102	65

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
				VENTILATION SUBTOTALS				

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load				
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.23	516	2194	2456

Project:	Burton Estate			Page:		of	26	Date:	
Room:	109 Master Closet			Name:	Cody Knuth				
Cooling: Outside db	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db	2.5	*Inside db*	74	*Re: Tbl 1*					

EXTERNAL LOADS

TRANSMISSION

	ITEM	EXPOS-URE	AREA	U	U X A	HTG ΔT	TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	N				71.5				
		S				71.5				
		E				71.5				
		W				71.5				
						71.5				
	Glass					71.5		22.6		
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		30	0.0229	0.69	71.5		58	40	49
7V,17	FLOOR					71.5				
							TRANSMISSION SUBTOTALS		40	49

SOLAR

ITEM		AREA	EXPOS-URE	Tbl 2A,2B SF	Tbl 3 SHGF		BTUh COOLING LOAD
GLASS	windows		N				
	doors						
GLASS	windows		S				
	doors						
GLASS	windows		E				
	doors						
GLASS	windows		W				
	doors						
						SOLAR SUBTOTAL	

INTERNAL LOADS

ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
30	0.014	0		Incand.	Watts x 3.413 = BTUh	1
				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
					ELECT SUBTOTAL	1

PEOPLE

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea	CLG LAT LOAD	CLG SENS LOAD

EQUIP

EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12	CLG LAT LOAD	CLG SENS LOAD
					EQUIPMENT SUBTOTALS		

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG	2	Q_L = CFM x .69 x ΔG	71.5	22.6	40	55.2	49	
Space HTG	2	Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			154
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
				INFILTRATION SUBTOTALS		55.2	48.816	154.44

	CLG LAT	CLG SENS	HEATING
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration	55	90	204
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		4	5

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
				VENTILATION SUBTOTALS				

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load				
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.01	55	90	204

	Project:	Burton Estate			Page:		of	26	Date:	
	Room:	110 Spare Coset			Name:	Cody Knuth				
	Cooling: Outside db		97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains* 40
	Heating: Outside db		2.5	*Inside db*	74	*Re: Tbl 1*			Tbl 8 & 9	BTUh / BTUh
EXTERNAL LOADS – TRANSMISSION	ITEM	EXPOS-URE	AREA	U	U X A	HTG ΔT	Aug TIME	ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	N				71.5				
		S	26.66	0.06	1.60	71.5	14	57	91	114
		E				71.5				
		W				71.5				
						71.5				
	Glass					71.5		22.6		
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,71	ROOF/CEILING		28.89	0.0229	0.66	71.5	14	58	38	47
7V,17	FLOOR					71.5				
						TRANSMISSION SUBTOTALS			130	162
EXTERNAL LOADS – SOLAR	ITEM		AREA	EXPOS-URE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows		N						
		doors								
	GLASS	windows		S						
		doors								
	GLASS	windows		E						
		doors								
	GLASS	windows		W						
		doors								
							SOLAR SUBTOTAL			
INTERNAL LOADS – ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts						CLG SENS LOAD	
	28.9				Incand.	Watts x 3.413 = BTUh				
					Fluor.	Watts x 4.1 = BTUh				
						Watts x 3.413 = BTUh				
							ELECT SUBTOTAL			
INTERNAL LOADS – PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD	
INTERNAL LOADS – EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12				
					EQUIPMENT SUBTOTALS					
INFILT	Tbl 13A & 13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG	1.926	Q_L = CFM x .69 x ΔG		71.5	22.6	40	53.1576	47	
	Space HTG	1.926	Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			149
	Door CLG				71.5	22.6	40			
	Door HTG				71.5	22.6	40			
					INFILTRATION SUBTOTALS			53.1576	47.00981	148.7257
	Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration							53	177	310
									CLG CFM	HTG CFM
	Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)								8	8
VENT	Tbl 14 ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG		71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			
					VENTILATION SUBTOTALS					
	Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load									
	Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =				0.02			53	177	310

Project:	Burton Estate				Page:		of	26	Date:	
Room:	111 Spare Bedroom				Name:	Cody Knuth				
Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*					

EXTERNAL LOADS — TRANSMISSION

ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	Aug TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
Wall	N				71.5				
	S	87.75	0.06	5.27	71.5	14	57	300	376
	E				71.5				
	W	96	0.061	5.86	71.5	14	37	217	419
					71.5				
Glass		12.25	0.5	6.13	71.5	14	22.6	138	438
					71.5		22.6		
Partitions					71.5		22.6		
					71.5		22.6		
Doors					71.5				
					71.5				
					71.5				
7S,7T ROOF/CEILING		150	0.0229	3.44	71.5	14	58	199	246
7V,17 FLOOR					71.5				
TRANSMISSION SUBTOTALS								854	1479

EXTERNAL LOADS — SOLAR

ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF	CLG LOAD
GLASS	windows		N			
	doors					
GLASS	windows	12.25	S	0.35	124	532
	doors					
GLASS	windows		E			
	doors					
GLASS	windows		W			
	doors					
SOLAR SUBTOTAL						532

INTERNAL LOADS — ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
150	0.006	1		Incand.	Watts x 3.413 = BTUh	3
				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
ELECT SUBTOTAL						3

INTERNAL LOADS — PEOPLE / EQUIP

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea				CLG LAT LOAD	CLG SENS LOAD
EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12		
EQUIPMENT SUBTOTALS							

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG	10	Q_L = CFM x .69 x ΔG	71.5	22.6	40	276	244	
Space HTG	10	Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			772
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
INFILTRATION SUBTOTALS						276	244.08	772.2

	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration	276	1633	2251
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		76	60

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
VENTILATION SUBTOTALS								

		CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load				
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.16	276	1633	2251

Project:	Burton Estate				Page:		of	26	Date:	
Room:	112 Spare Bathroom				Name:	Cody Knuth				
Cooling: Outside db		97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db		2.5	*Inside db*	74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS / TRANSMISSION	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N				71.5				
		S				71.5				
		E				71.5				
		W	44	0.061	2.68	71.5	17	79	212	192
						71.5				
	Glass					71.5		22.6		
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		68.75	0.0229	1.57	71.5	17	58	91	113
7V,17	FLOOR					71.5				
						TRANSMISSION SUBTOTALS			303	304
SOLAR	ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows		N						
		doors								
	GLASS	windows		S						
		doors								
	GLASS	windows		E						
		doors								
	GLASS	windows		W						
		doors								
								SOLAR SUBTOTAL		
INTERNAL LOADS / ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts						CLG SENS LOAD	
	68.75	0.024	2		Incand.	Watts x 3.413 = BTUh			6	
					Fluor.	Watts x 4.1 = BTUh				
						Watts x 3.413 = BTUh				
								ELECT SUBTOTAL	6	
PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD	
EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12				
					EQUIPMENT SUBTOTALS					
INFILT	Tbl 13A & 13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG	4.583333	Q_L = CFM x .69 x ΔG		71.5	22.6	40	126.5	112	
	Space HTG	4.583333	Q_s = CFM x 1.08 x ΔT		71.5	22.6	40			354
	Door CLG				71.5	22.6	40			
	Door HTG				71.5	22.6	40			
					INFILTRATION SUBTOTALS			126.5	111.87	353.925
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration								127	421	658
									CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)									19	17
VENT	Tbl 14 ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG		71.5	22.6	40			
			Q_s = CFM x 1.08 x ΔT		71.5	22.6	40			
					VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load										
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =					0.05			127	421	658

Project:	Burton Estate				Page:		of	26	Date:	
Room:	113 Den				Name:	Cody Knuth				
Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS / TRANSMISSION	ITEM	EXPOS-URE	AREA	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N	51.75	0.06	3.11	71.5	17	33	102	222
		S				71.5				
		E				71.5				
		W	96	0.061	5.86	71.5	17	79	463	419
						71.5				
	Glass		12.25	0.5	6.13	71.5	17	22.6	138	438
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,7T	ROOF/CEILING		121	0.0229	2.77	71.5	17	58	161	198
7V,17	FLOOR					71.5				
					TRANSMISSION SUBTOTALS				864	1277
SOLAR	ITEM		AREA	EXPOS-URE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows	12.25	N	0.35	32			137	
		doors								
	GLASS	windows		S						
		doors								
	GLASS	windows		E						
		doors								
	GLASS	windows		W						
		doors								
							SOLAR SUBTOTAL		137	
INTERNAL LOADS / ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts						CLG SENS LOAD	
	121	0.083	10		Incand.	Watts x 3.413 = BTUh			34	
					Fluor.	Watts x 4.1 = BTUh				
						Watts x 3.413 = BTUh				
							ELECT SUBTOTAL		34	
PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD	
EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12				
	1		500	Computer					500	
					EQUIPMENT SUBTOTALS				500	
INFILT	Tbl 13A & 13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG	8.066667	Q_L = CFM x .69 x ΔG		71.5	22.6	40	222.64	197	
	Space HTG	8.066667	Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			623
	Door CLG				71.5	22.6	40			
	Door HTG				71.5	22.6	40			
					INFILTRATION SUBTOTALS			222.64	196.8912	622.908
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration								223	1733	1900
									CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)									80	50
VENT	Tbl 14 ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG		71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			
					VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load										
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =					0.16			223	1733	1900

Project:	Burton Estate			Page:		of	26	Date:	
Room:	114 Den Closet			Name:	Cody Knuth				
Cooling: Outside db	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db	2.5	*Inside db*	72	*Re: Tbl 1*					

EXTERNAL LOADS — TRANSMISSION

	ITEM	EXPOS-URE	AREA	U	U X A	HTG ΔT	TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	N				69.5				
		S				69.5				
		E				69.5				
		W				69.5				
						69.5				
	Glass					69.5		22.6		
						69.5		22.6		
	Partitions					69.5		22.6		
						69.5		22.6		
	Doors					69.5				
						69.5				
						69.5				
7S,7T	ROOF/CEILING		21	0.0229	0.48	69.5		58	28	33
7V,17	FLOOR					69.5				
							TRANSMISSION SUBTOTALS		28	33

EXTERNAL LOADS — SOLAR

ITEM		AREA	EXPOS-URE	Tbl 2A,2B SF	Tbl 3 SHGF		
GLASS	windows		N				
	doors						
GLASS	windows		S				
	doors						
GLASS	windows		E				
	doors						
GLASS	windows		W				
	doors						
						SOLAR SUBTOTAL	

INTERNAL LOADS — ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
21				Incand.	Watts x 3.413 = BTUh	
				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
					ELECT SUBTOTAL	

INTERNAL LOADS — PEOPLE

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea	CLG LAT LOAD	CLG SENS LOAD

INTERNAL LOADS — EQUIP

EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12		
					EQUIPMENT SUBTOTALS		

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG	1.4	Q_L = CFM x .69 x ΔG	69.5	22.6	40	38.64	34	
Space HTG	1.4	Q_S = CFM x 1.08 x ΔT	69.5	22.6	40			105
Door CLG			69.5	22.6	40			
Door HTG			69.5	22.6	40			
			INFILTRATION SUBTOTALS			38.64	34.1712	105.084

Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration	39	62	139
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		3	4

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	69.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	69.5	22.6	40			
			VENTILATION SUBTOTALS					

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load					
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.01		39	62	139

Project:	Burton Estate			Page:		of	26	Date:	
Room:	115 Corridor			Name:	Cody Knuth				
Cooling: Outside db	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db	2.5	*Inside db*	74	*Re: Tbl 1*					

EXTERNAL LOADS

TRANSMISSION

	ITEM	EXPOS-URE	AREA	U	U X A	HTG ΔT	TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	N				71.5				
		S				71.5				
		E				71.5				
		W				71.5				
						71.5				
	Glass					71.5		22.6		
						71.5		22.6		
	Partitions					71.5		22.6		
						71.5		22.6		
	Doors					71.5				
						71.5				
						71.5				
7S,71	ROOF/CEILING		70.83	0.0229	1.62	71.5		58	94	116
7V,17	FLOOR					71.5				
						TRANSMISSION SUBTOTALS			94	116

SOLAR

ITEM		AREA	EXPOS-URE	Tbl 2A,2B SF	Tbl 3 SHGF		BTUh COOLING LOAD
GLASS	windows		N				
	doors						
GLASS	windows		S				
	doors						
GLASS	windows		E				
	doors						
GLASS	windows		W				
	doors						
						SOLAR SUBTOTAL	

INTERNAL LOADS

ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
70.83	0.01	1		Incand.	Watts x 3.413 = BTUh	2
				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
					ELECT SUBTOTAL	2

PEOPLE

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea	CLG LAT LOAD	CLG SENS LOAD

EQUIP

EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12	CLG LAT LOAD	CLG SENS LOAD
					EQUIPMENT SUBTOTALS		

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG	4.722	Q_L = CFM x .69 x ΔG	71.5	22.6	40	130.3272	115	
Space HTG	4.722	Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			365
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
				INFILTRATION SUBTOTALS		130.3272	115.2546	364.6328

	CLG LAT	CLG SENS	HEATING
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration	130	212	481
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		10	13

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
				VENTILATION SUBTOTALS				

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load					
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.03		130	212	481

Project:		Burton Estate				Page:		of	26	Date:	
Room:		116 Stair				Name:	Cody Knuth				
Cooling:		*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating:		*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*					
EXTERNAL LOADS	TRANSMISSION	ITEM	EXPOSURE	AREA	U	U X A	HTG ΔT	TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
		Wall	N				71.5				
			S				71.5				
			E				71.5				
			W				71.5				
							71.5				
		Glass					71.5		22.6		
							71.5		22.6		
		Partitions					71.5		22.6		
							71.5		22.6		
		Doors					71.5				
							71.5				
							71.5				
	7S,7T	ROOF/CEILING		49.8	0.0229	1.14	71.5		58	66	82
	7V,17	FLOOR					71.5				
							TRANSMISSION SUBTOTALS			66	82
	SOLAR	ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
		GLASS	windows		N						
			doors								
		GLASS	windows		S						
			doors								
		GLASS	windows		E						
			doors								
		GLASS	windows		W						
			doors								
								SOLAR SUBTOTAL			
INTERNAL LOADS	ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts						CLG SENS LOAD	
		49.8	0.008	0		Incand.	Watts x 3.413 = BTUh			1	
						Fluor.	Watts x 4.1 = BTUh				
							Watts x 3.413 = BTUh				
								ELECT SUBTOTAL		1	
	PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD	
	EQUIP	EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12				
						EQUIPMENT SUBTOTALS					
INFILT		Tbl 13A & 13B ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Space CLG	3.32	Q_L = CFM x .69 x ΔG		71.5	22.6	40	91.632	81	
		Space HTG	3.32	Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			256
		Door CLG				71.5	22.6	40			
		Door HTG				71.5	22.6	40			
						INFILTRATION SUBTOTALS			91.632	81.03456	256.3704
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration									92	149	338
										CLG CFM	HTG CFM
		Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)								7	9
VENT		Tbl 14 ITEM	CFM			HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
				Q_L = CFM x .69 x ΔG		71.5	22.6	40			
				Q_S = CFM x 1.08 x ΔT		71.5	22.6	40			
						VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Load											
		Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =				0.02			92	149	338

Project:	Burton Residence				Page:		of	26	Date:	
Room:	001 Corridor				Name:	Cody Knuth				
Cooling: Outside db	97.6	*wb*		75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db	2.5	*Inside db*		74	*Re: Tbl 1*					

EXTERNAL LOADS	TRANSMISSION	ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
		Wall	N					71.5				
			S					71.5				
			E					71.5				
			W					71.5				
								71.5				
		Glass						71.5		22.6		
								71.5		22.6		
		Partitions						71.5		22.6		
								71.5		22.6		
		Doors						71.5				
								71.5				
								71.5				
	7S,7T	ROOF/CEILING						71.5				
	7V,17	FLOOR		33.25	1.7			71.5				57
									TRANSMISSION SUBTOTALS			57

SOLAR	ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF			
	GLASS	windows			N					
		doors								
	GLASS	windows			S					
		doors								
	GLASS	windows			E					
		doors								
	GLASS	windows			W					
		doors								
								SOLAR SUBTOTAL		

INTERNAL LOADS	ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts					CLG SENS LOAD
		33.25	0.008	0		Incand.	Watts x 3.413 = BTUh		1
						Fluor.	Watts x 4.1 = BTUh		
							Watts x 3.413 = BTUh		
							ELECT SUBTOTAL		1

	PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD
	EQUIP	EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12		
							EQUIPMENT SUBTOTALS			

INFILT	Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
	Space HTG		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
	Door CLG			71.5	22.6	40			
	Door HTG			71.5	22.6	40			
					INFILTRATION SUBTOTALS				
	Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration							1	57
								CLG CFM	HTG CFM
	Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)							0	2

VENT	Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG	71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
					VENTILATION SUBTOTALS				
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads									
	Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =			0.00				1	57

Project:	Burton Estate			Page:		of	26	Date:	
Room:	002 Spare Closet			Name:	Cody Knuth				
Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains* 40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*				

EXTERNAL LOADS

TRANSMISSION

ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	Aug. TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
Wall	S	14		0.3063	4.29	71.5	14	25	107	307
	S	14	7.5			71.5				105
	S					71.5				
	W					71.5				
						71.5				
Glass						71.5		22.6		
						71.5		22.6		
Partitions						71.5		22.6		
						71.5		22.6		
Doors						71.5				
						71.5				
						71.5				
7S,7T ROOF/CEILING						71.5				
7V,17 FLOOR		22.15	1.7			71.5				38
TRANSMISSION SUBTOTALS									107	450

SOLAR

ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF			BTUh COOLING LOAD
GLASS	windows			N					
	doors								
GLASS	windows			S					
	doors								
GLASS	windows			E					
	doors								
GLASS	windows			W					
	doors								
SOLAR SUBTOTAL									

INTERNAL LOADS

ELECT

LIGHTS / POWER	W/Fix or W/SF	Total Watts					CLG SENS LOAD
22.15	0.019	0			Incand.	Watts x 3.413 = BTUh	1
					Fluor.	Watts x 4.1 = BTUh	
						Watts x 3.413 = BTUh	
ELECT SUBTOTAL							1

PEOPLE

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea				CLG LAT LOAD	CLG SENS LOAD

EQUIP

EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12	CLG LAT LOAD	CLG SENS LOAD
EQUIPMENT SUBTOTALS								

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
Space HTG		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
INFILTRATION SUBTOTALS								

Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration		109	450
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		5	12

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
VENTILATION SUBTOTALS								

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads					
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.01			109	450

Project:	Burton Estate	Page:		of	26	Date:
Room:	003 Spare Bedroom	Name:	Cody Knuth		

Cooling: Outside db	97.6	*wb*		75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db	2.5	*Inside db*		74	*Re: Tbl 1*					

EXTERNAL LOADS

TRANSMISSION

	ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
	Wall	S	42.25		0.3063	12.94	71.5	17	39	505	925
		S	42.25	7.5			71.5				317
		W	56		0.3063	17.15	71.5	17	56	961	1226
		W	56	7.5			71.5				420
							71.5				
	Glass		3.75		0.81	3.04	71.5	17	22.6	69	217
							71.5		22.6		
	Partitions						71.5		22.6		
							71.5		22.6		
	Doors						71.5				
							71.5				
							71.5				
7S,7T	ROOF/CEILING						71.5				
7V,17	FLOOR		181.25	1.7			71.5				308
								TRANSMISSION SUBTOTALS		1534	3414

SOLAR

ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF			COOLING LOAD
GLASS	windows			N					
	doors								
GLASS	windows	3.75		S	0.35	124			163
	doors								
GLASS	windows			E					
	doors								
GLASS	windows			W					
	doors								
							SOLAR SUBTOTAL		163

INTERNAL LOADS

ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts					CLG SENS LOAD
181.25	0.001	0			Incand.	Watts x 3.413 = BTUh	1
					Fluor.	Watts x 4.1 = BTUh	
						Watts x 3.413 = BTUh	
						ELECT SUBTOTAL	1

PEOPLE / EQUIP

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD
1	200	250					200	250
EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12		
					EQUIPMENT SUBTOTALS		200	250

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
Space HTG		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
			INFILTRATION SUBTOTALS					
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration						200	1947	3414
							CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)							90	90

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
			VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads								
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =			0.18			200	1947	3414

Project:	Burton Estate					Page:		of	26	Date:	
Room:	004 Spare Bathroom					Name:	Cody Knuth				
Cooling: Outside db		97.6	*wb*		75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db		2.5	*Inside db*		74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS / TRANSMISSION	ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	W	12.66		0.3063	3.88	71.5	17	56	217	277
		W	12.66	7.5			71.5				95
		W					71.5				
		W					71.5				
							71.5				
	Glass						71.5		22.6		
							71.5		22.6		
	Partitions						71.5		22.6		
							71.5		22.6		
	Doors						71.5				
							71.5				
							71.5				
7S,7T	ROOF/CEILING						71.5				
7V,17	FLOOR		52.5	1.7			71.5				89
	TRANSMISSION SUBTOTALS									217	461
EXTERNAL LOADS / SOLAR	ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows			N						
		doors									
	GLASS	windows			S						
		doors									
	GLASS	windows			E						
		doors									
	GLASS	windows			W						
		doors									
	SOLAR SUBTOTAL										
INTERNAL LOADS / ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts							CLG SENS LOAD	
	52.5	0.021	1			Incand.	Watts x 3.413 = BTUh			4	
						Fluor.	Watts x 4.1 = BTUh				
							Watts x 3.413 = BTUh				
	ELECT SUBTOTAL									4	
INTERNAL LOADS / PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea						CLG LAT LOAD	CLG SENS LOAD	
INTERNAL LOADS / EQUIP	EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12				
	EQUIPMENT SUBTOTALS										
INFILT	Tbl 13A & 13B ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG		Q_L = CFM x .69 x ΔG			71.5	22.6	40			
	Space HTG		Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
	Door CLG					71.5	22.6	40			
	Door HTG					71.5	22.6	40			
	INFILTRATION SUBTOTALS										
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration										221	461
										CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)										10	12
VENT	Tbl 14 ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG			71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
	VENTILATION SUBTOTALS										
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads											
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =						0.02				221	461

Project:	Burton Estate					Page:		of	26	Date:	
Room:	005 Closet					Name:	Cody Knuth				
Cooling: Outside db		97.6	*wb*		75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db		2.5	*Inside db*		74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS – TRANSMISSION	ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N					71.5				
		S					71.5				
		E					71.5				
		W					71.5				
							71.5				
	Glass						71.5		22.6		
							71.5		22.6		
	Partitions						71.5		22.6		
							71.5		22.6		
	Doors						71.5				
							71.5				
							71.5				
7S,7T	ROOF/CEILING						71.5				
7V,17	FLOOR		7.77	1.7			71.5				13
	TRANSMISSION SUBTOTALS										13
SOLAR	ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows			N						
		doors									
	GLASS	windows			S						
		doors									
	GLASS	windows			E						
		doors									
	GLASS	windows			W						
		doors									
	SOLAR SUBTOTAL										
INTERNAL LOADS – ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts							CLG SENS LOAD	
	7.72					Incand.	Watts x 3.413 = BTUh				
						Fluor.	Watts x 4.1 = BTUh				
							Watts x 3.413 = BTUh				
	ELECT SUBTOTAL										
PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea						CLG LAT LOAD	CLG SENS LOAD	
EQUIP	EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12				
	EQUIPMENT SUBTOTALS										
INFILT	Tbl 13A & 13B ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG		Q_L = CFM x .69 x ΔG			71.5	22.6	40			
	Space HTG		Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
	Door CLG					71.5	22.6	40			
	Door HTG					71.5	22.6	40			
	INFILTRATION SUBTOTALS										
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration											13
										CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)											0
VENT	Tbl 14 ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG			71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
	VENTILATION SUBTOTALS										
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads											
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =											13

Project:	Burton Estate					Page:		of	26	Date:	
Room:	006 Lounge					Name:	Cody Knuth				
Cooling: Outside db		97.6	*wb*		75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db		2.5	*Inside db*		74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS / TRANSMISSION	ITEM	EXPOS-URE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N	32.66		0.3063	10.00	71.5	17	20	200	715
		N	32.66	7.5			71.5				245
		W	50		0.3063	15.32	71.5	17	56	858	1095
		W	50	7.5			71.5				375
	Glass						71.5		22.6		
							71.5		22.6		
	Partitions						71.5		22.6		
							71.5		22.6		
	Doors						71.5				
							71.5				
							71.5				
7S,7T	ROOF/CEILING						71.5				
7V,17	FLOOR		205.25	1.7			71.5				349
						TRANSMISSION SUBTOTALS				1058	2779
SOLAR	ITEM		AREA		EXPOS-URE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows			N						
		doors									
	GLASS	windows			S						
		doors									
	GLASS	windows			E						
		doors									
	GLASS	windows			W						
		doors									
							SOLAR SUBTOTAL				
INTERNAL LOADS / ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts							CLG SENS LOAD	
						Incand.	Watts x 3.413 = BTUh				
	205.25	0.009	2			Fluor.	Watts x 4.1 = BTUh			8	
							Watts x 3.413 = BTUh				
							ELECT SUBTOTAL			8	
PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea						CLG LAT LOAD	CLG SENS LOAD	
EQUIP	EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12				
						EQUIPMENT SUBTOTALS					
INFILT	Tbl 13A & 13B ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG		Q_L = CFM x .69 x ΔG			71.5	22.6	40			
	Space HTG		Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
	Door CLG					71.5	22.6	40			
	Door HTG					71.5	22.6	40			
						INFILTRATION SUBTOTALS					
	Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration									1065	2779
										CLG CFM	HTG CFM
	Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)									49	74
VENT	Tbl 14 ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG			71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
						VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads											
	Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =					0.09				1065	2779

Project:	Burton Estate			Page:		of	26	Date:	
Room:	007 Living Room			Name:	Cody Knuth				
Cooling: Outside db	97.6	*wb*	75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db	2.5	*Inside db*	74	*Re: Tbl 1*					

EXTERNAL LOADS

TRANSMISSION

ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
Wall	E	106.25		0.3063	32.54	71.5	10	23	749	2327
	E	106.25	7.5			71.5				797
	W	55.34		0.3063	16.95	71.5	10	20	339	1212
	W	55.34	7.5			71.5				415
						71.5				
Glass		3.75		0.81	3.04	71.5	10	22.6	69	217
						71.5		22.6		
Partitions						71.5		22.6		
						71.5		22.6		
Doors						71.5				
						71.5				
						71.5				
7S,7T ROOF/CEILING						71.5				
7V,17 FLOOR		467.54	1.7			71.5				795
TRANSMISSION SUBTOTALS									1156	5763

SOLAR

ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF	COOLING LOAD
GLASS	windows			N			
	doors						
GLASS	windows			S			
	doors						
GLASS	windows	3.75		E	0.35	164	215
	doors						
GLASS	windows			W			
	doors						
SOLAR SUBTOTAL							215

INTERNAL LOADS

ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts					CLG SENS LOAD
					Incand.	Watts x 3.413 = BTUh	
467.54	0.086	40			Fluor.	Watts x 4.1 = BTUh	165
						Watts x 3.413 = BTUh	
ELECT SUBTOTAL							165

PEOPLE / EQUIP

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea					CLG LAT LOAD	CLG SENS LOAD
EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12		
EQUIPMENT SUBTOTALS								

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
Space HTG		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
INFILTRATION SUBTOTALS								

Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration		1536	5763
		CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)		71	152

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
VENTILATION SUBTOTALS								

Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads				
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =	0.13		1536	5763

Project:	Burton Estate					Page:		of	26	Date:	
Room:	008 Storage					Name:	Cody Knuth				
Cooling: Outside db		97.6	*wb*		75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db		2.5	*Inside db*		74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS – TRANSMISSION	ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N	26.66		0.3063	8.17	71.5	18	21	171	584
		N	26.66	7.5			71.5				200
		S	16.334		0.3063	5.00	71.5	18	22	110	358
		S	16.334	7.5			71.5				123
							71.5				
	Glass						71.5		22.6		
							71.5		22.6		
	Partitions						71.5		22.6		
							71.5		22.6		
	Doors						71.5				
							71.5				
							71.5				
7S,7T	ROOF/CEILING						71.5				
7V,17	FLOOR		245.75	1.7			71.5				418
						TRANSMISSION SUBTOTALS				282	1682
EXTERNAL LOADS – SOLAR	ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows			N						
		doors									
	GLASS	windows			S						
		doors									
	GLASS	windows			E						
		doors									
	GLASS	windows			W						
		doors									
								SOLAR SUBTOTAL			
INTERNAL LOADS – ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts							CLG SENS LOAD	
						Incand.	Watts x 3.413 = BTUh				
	245.75	0.004	1			Fluor.	Watts x 4.1 = BTUh			4	
							Watts x 3.413 = BTUh				
								ELECT SUBTOTAL		4	
INTERNAL LOADS – PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea						CLG LAT LOAD	CLG SENS LOAD	
INTERNAL LOADS – EQUIP	EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12				
					EQUIPMENT SUBTOTALS						
INFILT	Tbl 13A & 13B ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG		Q_L = CFM x .69 x ΔG			71.5	22.6	40			
	Space HTG		Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
	Door CLG					71.5	22.6	40			
	Door HTG					71.5	22.6	40			
					INFILTRATION SUBTOTALS						
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration										286	1682
										CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)										13	44
VENT	Tbl 14 ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG			71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
					VENTILATION SUBTOTALS						
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads											
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =						0.02				286	1682

Project:	Burton Estate					Page:		of	26	Date:	
Room:	009 Fitness					Name:	Cody Knuth				
Cooling: Outside db		97.6	*wb*		75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db		2.5	*Inside db*		74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS / TRANSMISSION	ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N	47.33		0.3063	14.50	71.5	10	14	203	1037
		N	47.33	7.5			71.5				355
		E	54		0.3063	16.54	71.5	10	23	380	1183
		E	54	7.5			71.5				405
							71.5				
	Glass						71.5		22.6		
							71.5		22.6		
	Partitions						71.5		22.6		
							71.5		22.6		
	Doors						71.5				
							71.5				
							71.5				
7S,7T	ROOF/CEILING						71.5				
7V,17	FLOOR		180.84	1.7			71.5				307
	TRANSMISSION SUBTOTALS									583	3286
SOLAR	ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows			N						
		doors									
	GLASS	windows			S						
		doors									
	GLASS	windows			E						
		doors									
	GLASS	windows			W						
		doors									
	SOLAR SUBTOTAL										
INTERNAL LOADS / ELECT	LIGHTS / POWER	W/Fix or W/SF	Total Watts							CLG SENS LOAD	
						Incand.	Watts x 3.413 = BTUh				
	180.84	0.018	3			Fluor.	Watts x 4.1 = BTUh			13	
							Watts x 3.413 = BTUh				
	ELECT SUBTOTAL									13	
PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea						CLG LAT LOAD	CLG SENS LOAD	
EQUIP	EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12				
	EQUIPMENT SUBTOTALS										
INFILT	Tbl 13A & 13B ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG		Q_L = CFM x .69 x ΔG			71.5	22.6	40			
	Space HTG		Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
	Door CLG					71.5	22.6	40			
	Door HTG					71.5	22.6	40			
	INFILTRATION SUBTOTALS										
	Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration									597	3286
										CLG CFM	HTG CFM
	Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)									28	87
VENT	Tbl 14 ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG			71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
	VENTILATION SUBTOTALS										
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads											
	Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =					0.05				597	3286

Project:		Burton Estate					Page:		of	26	Date:	
Room:		010 Laundry					Name:	Cody Knuth				
Cooling: Outside db			97.6	*wb*		75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating: Outside db			2.5	*Inside db*		74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS	TRANSMISSION	ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
		Wall	S	58		0.3063	17.77	71.5	10	17	302	1270
			S	58	7.5			71.5				435
			E	58.92		0.3063	18.05	71.5	10	23	415	1290
			E	58.92	7.5			71.5				442
								71.5				
		Glass		3.75		0.81	3.04	71.5	10	22.6	69	217
								71.5		22.6		
		Partitions						71.5		22.6		
								71.5		22.6		
		Doors						71.5				
								71.5				
								71.5				
	7S,7T	ROOF/CEILING						71.5				
	7V,17	FLOOR		227	1.7			71.5				386
									TRANSMISSION SUBTOTALS		786	4041
	SOLAR	ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
		GLASS	windows			N						
			doors									
		GLASS	windows			S						
			doors									
		GLASS	windows	3.75		E	0.35	164			215	
			doors									
		GLASS	windows			W						
			doors									
										SOLAR SUBTOTAL	215	
INTERNAL LOADS	ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts							CLG SENS LOAD	
		227	0.008	2			Incand.	Watts x 3.413 = BTUh			6	
							Fluor.	Watts x 4.1 = BTUh				
								Watts x 3.413 = BTUh				
										ELECT SUBTOTAL	6	
	PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea						CLG LAT LOAD	CLG SENS LOAD	
	EQUIP	EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12				
		1		4000							4000	
								EQUIPMENT SUBTOTALS			4000	
INFILT		Tbl 13A & 13B ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Space CLG		Q_L = CFM x .69 x ΔG			71.5	22.6	40			
		Space HTG		Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
		Door CLG					71.5	22.6	40			
		Door HTG					71.5	22.6	40			
							INFILTRATION SUBTOTALS					
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration											5007	4041
											CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)											232	107
VENT		Tbl 14 ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
				Q_L = CFM x .69 x ΔG			71.5	22.6	40			
				Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
							VENTILATION SUBTOTALS					
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads												
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =							0.42				5007	4041

Block Loads

The heat transfer loads were also calculated for the “block” load of the residence. In Table A-3, the heat transfer calculations were completed using a traditional commercial calculation process. The external, internal, and infiltration loads were calculated for each room in the residence. And, again, no ventilation was accounted for. A block load was calculated to size the furnace and DX coil for the HVAC system. In Table A-4, the block load was calculated without including any lighting in the residence.

Table A-3 Block Load Calculation Spreadsheet

Project:	Burton Residence					Page:	1	of	1	Date:	7/31/2012
Room:	Block Load					Name:	Cody Knuth				
Cooling:	*Outside db*	97.6	*wb*		75.6	*Inside db*	75	*RH %*	50	*ΔGrains*	40
Heating:	*Outside db*	2.5	*Inside db*		74	*Re: Tbl 1*			Tbl 8 & 9	BTUh	BTUh
EXTERNAL LOADS / TRANSMISSION	ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	ΔT or ETD	COOLING LOAD	HEATING LOAD
	Wall	N	204.75		0.06	12.29	71.5	10	19	233	878
		N	106.65		0.3063	32.67	71.5	10	14	457	2336
	Below Grade	N	106.25	7.5			71.5	10			797
		S	229.07		0.06	13.74	71.5	10	30	412	983
		S	51.75		0.061	3.16	71.5	10	19	60	226
		S	130.58		0.3063	40.00	71.5	10	17	680	2860
	Below Grade	S	130.58	7.5			71.5	10			979
		E	420		0.06	25.20	71.5	10	62	1562	1802
		E	219.17		0.3063	67.13	71.5	10	23	1544	4800
	Below Grade	E	219.17	7.5			71.5	10			1644
		W	236		0.061	14.40	71.5	10	24	346	1029
		W	102		0.06	6.12	71.5	10	18	110	438
		W	174		0.3063	53.30	71.5	10	20	1066	3811
	Below Grade	W	174	7.5			71.5	10			1305
							71.5				
	Glass		235.37		0.5	117.69	71.5	10	22.6	2660	8414
	Vestibule		24		0.79	18.96	71.5	10	22.6	428	1356
	Basement		11.25		0.81	9.11	71.5	10	22.6	206	652
							71.5		22.6		
	Partitions		100		0.06	6.00	37	10	22.6		222
							71.5		22.6		
	Doors		59.62		0.365	21.76	71.5	10	22.6	492	1556
							71.5				
							71.5				
7S,7T	ROOF/CEILING		1776.5		0.0229	40.68	71.5	10	58	2360	2909
7V,17	FLOOR		1511.11	1.7			71.5				4453
	TRANSMISSION SUBTOTALS									12616	43448
SOLAR	ITEM		AREA		EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF				
	GLASS	windows	59.25		N	0.35	32			664	
		doors									
	GLASS	windows	28.25		S	0.35	124			1226	
		doors									
	GLASS	windows	151.6		E	0.35	164			8702	
		doors									
	GLASS	windows	44.75		W	0.35	156			2443	
		windows	24			0.35	116			974	
	SOLAR SUBTOTAL									14009	
INTERNAL LOADS / ELECT	LIGHTS / POWER	W/Fixt or W/SF	Total Watts							CLG SENS LOAD	
		1	2008			Incand.	Watts x 3.413 = BTUh			6853	
		1	880			Fluor.	Watts x 4.1 = BTUh			3608	
							Watts x 3.413 = BTUh				
	ELECT SUBTOTAL									10461	
PEOPLE	Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea						CLG LAT LOAD	CLG SENS LOAD	
	2	200	250						400	500	
EQUIP	EQUIP	LATENT	SENS		Hooded	Unhooded	Tbl 11, 11A, 12				
	1		3900							3900	
	1	3010	1040						3010	1040	
	EQUIPMENT SUBTOTALS								3410	5440	
INFILT	Tbl 13A & 13B ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
	Space CLG	118	Q_L = CFM x .69 x ΔG			71.5	22.6	40	3256.8	2880	
	Space HTG	118	Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			9112
	Door CLG					71.5	22.6	40			
	Door HTG					71.5	22.6	40			
	INFILTRATION SUBTOTALS								3256.8	2880.144	9111.96
	Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration								6667	45407	52560
										CLG CFM	HTG CFM
	Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)									2102	1390
VENT	Tbl 14 ITEM	CFM				HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
			Q_L = CFM x .69 x ΔG			71.5	22.6	40			
			Q_S = CFM x 1.08 x ΔT			71.5	22.6	40			
	VENTILATION SUBTOTALS										
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads											
	Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =					4.34			6667	45407	52560

Table A-4 Block Load Calculation Spreadsheet without Lighting

Project:	Burton Residence		Page:	1	of	1	Date:	7/31/2012
Room:	Block Load		Name:	Cody Knuth				
Cooling:	*Outside db*	97.6	*wb*	75.6	*Inside db* 75	*RH %* 50	*ΔGrains*	40
Heating:	*Outside db*	2.5	*Inside db*	74	*Re: Tbl 1*			

EXTERNAL LOADS — TRANSMISSION

ITEM	EXPOSURE	AREA	BTUh/ S.F.	U	U X A	HTG ΔT	July TIME	Tbl 8 & 9 ΔT or ETD	BTUh COOLING LOAD	BTUh HEATING LOAD
Wall	N	204.75		0.06	12.29	71.5	10	19	233	878
	N	106.65		0.3063	32.67	71.5	10	14	457	2336
Below Grade	N	106.25	7.5			71.5	10			797
	S	229.07		0.06	13.74	71.5	10	30	412	983
	S	51.75		0.061	3.16	71.5	10	19	60	226
	S	130.58		0.3063	40.00	71.5	10	17	680	2860
Below Grade	S	130.58	7.5			71.5	10			979
	E	420		0.06	25.20	71.5	10	62	1562	1802
	E	219.17		0.3063	67.13	71.5	10	23	1544	4800
Below Grade	E	219.17	7.5			71.5	10			1644
	W	236		0.061	14.40	71.5	10	24	346	1029
	W	102		0.06	6.12	71.5	10	18	110	438
	W	174		0.3063	53.30	71.5	10	20	1066	3811
Below Grade	W	174	7.5			71.5	10			1305
						71.5				
Glass		235.37		0.5	117.69	71.5	10	22.6	2660	8414
Vestibule		24		0.79	18.96	71.5	10	22.6	428	1356
Basement		11.25		0.81	9.11	71.5	10	22.6	206	652
						71.5		22.6		
Partitions		100		0.06	6.00	37	10	22.6		222
						71.5		22.6		
Doors		59.62		0.365	21.76	71.5	10	22.6	492	1556
						71.5				
						71.5				
7S,7T ROOF/CEILING		1776.5		0.0229	40.68	71.5	10	58	2360	2909
7V,17 FLOOR		1511	1.7			71.5				4453
TRANSMISSION SUBTOTALS									12616	43448

EXTERNAL LOADS — SOLAR

ITEM		AREA	EXPOSURE	Tbl 2A,2B SF	Tbl 3 SHGF	COOLING LOAD
GLASS	windows	59.25	N	0.35	32	664
	doors					
GLASS	windows	28.25	S	0.35	124	1226
	doors					
GLASS	windows	151.6	E	0.35	164	8702
	doors					
GLASS	windows	44.75	W	0.35	156	2443
	windows	24		0.35	116	974
SOLAR SUBTOTAL						14009

INTERNAL LOADS — ELECT

LIGHTS / POWER	W/Fixt or W/SF	Total Watts				CLG SENS LOAD
				Incand.	Watts x 3.413 = BTUh	
				Fluor.	Watts x 4.1 = BTUh	
					Watts x 3.413 = BTUh	
ELECT SUBTOTAL						

INTERNAL LOADS — PEOPLE / EQUIP

Tbl 15 # of PEOPLE	Table 10 LATENT BTUh/ea	SENS BTUh/ea				CLG LAT LOAD	CLG SENS LOAD
2	200	250				400	500
EQUIP	LATENT	SENS	Hooded	Unhooded	Tbl 11, 11A, 12		
1		3900					3900
1	3010	1040				3010	1040
EQUIPMENT SUBTOTALS						3410	5440

INFILT

Tbl 13A & 13B ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
Space CLG	118	Q_L = CFM x .69 x ΔG	71.5	22.6	40	3256.8	2880	
Space HTG	118	Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			9112
Door CLG			71.5	22.6	40			
Door HTG			71.5	22.6	40			
INFILTRATION SUBTOTALS						3256.8	2880.144	9111.96
Cooling & Heating Space Load Subtotals = Conduction + Solar + Internal + Infiltration						6667	34946	52560
							CLG CFM	HTG CFM
Required Supply Air CFM = Sensible Space Load Subtotals / 1.08 (SA - RA ΔT)							1618	1390

VENT

Tbl 14 ITEM	CFM		HTG ΔT	CLG ΔT	CLG ΔG	CLG LAT LOAD	CLG SENS LOAD	HEATING LOAD
		Q_L = CFM x .69 x ΔG	71.5	22.6	40			
		Q_S = CFM x 1.08 x ΔT	71.5	22.6	40			
VENTILATION SUBTOTALS								
Cooling & Heating Equipment Loads = Space Load Subtotals + Ventilation Loads								
Cooling Tons = (Clg Lat + Clg Sens) / 12,000 =			3.47			6667	34946	52560

U-Values

The U-values for the roof, door, and each wall have been calculated and included in this Appendix for reference.

Table A-5 U-Value Tables

Upper Level Masonry Wall		
Wall Construction	K-Factor [(Btu·in)/(ft²·°F·h/)]	R-Value [(ft²·°F·h)/Btu]
Outside Air Film		0.1700
4" Stone Veneer		0.3200
1/2" Cellotex Sheathing		1.3200
3.5" Fiberglass	0.26	13.4615
1/2" Sheet Rock	1.1	0.4545
Inside Air Film		0.6800
Total R Value		16.4061
U Value [BTU/(h °F ft²)]		**0.0610**

Upper Level Siding		
Wall Construction	K-Factor [(Btu·in)/(ft²·°F·h/)]	R-Value [(ft²·°F·h)/Btu]
Outside Air Film		0.1700
3/8"Plywood		0.5900
1/2" Cellotex Sheathing		1.3200
3.5" Fiberglass	0.26	13.4615
1/2" Sheet Rock	1.1	0.4545
Inside Air Film		0.6800
Total R Value		16.6761
U Value		**0.0600**

Lower Level Concrete Wall		
Wall Construction	K-Factor [(Btu·in)/(ft²·°F·h/)]	R-Value [(ft²·°F·h)/Btu]
Outside Air Film		0.1700
8" Concrete		0.6400
1/2" Cellotex Sheathing		1.3200
1/2" Sheet Rock	1.1	0.4545
Inside Air Film		0.6800
Total R Value		3.2645
U Value		**0.3063**

Roof Construction		
Roof Construction	K-Factor [(Btu·in)/(ft²·°F·h/)]	R-Value [(ft²·°F·h)/Btu]
Outside Air Film		0.1700
11" Fiberglass	0.26	42.3077
1/2" Sheet Rock	1.1	0.4545
Inside Air Film		0.6800
Total R Value		43.6122
U Value		**0.0229**

Door Construction		
Door Construction	K-Factor [(Btu·in)/(ft²·°F·h/)]	R-Value [(ft²·°F·h)/Btu]
Outside Air Film		0.1700
Fir, 1.5 in.		1.8900
Inside Air Film		0.6800
Total R Value		2.7400
U Value		**0.3650**

Appendix B - Existing Residential Performance Data

Data was retrieved from the homeowner to gauge the existing building's energy use and estimate what it could be going forward. Utility bills dating back 10 years were available and used to see a trend and find an average annual utility bill. All data used in this research can be found below.

Annual Utility Bills

The best indicator of future energy use for an existing residence is past energy use. The homeowner provided utility bills dating back several years and, for this research, a range of bills from January 2006 to November 2011 was used. The monthly bills were analyzed and the total kilowatts and MCF's used were recorded along with their respective costs. The data was then averaged to calculate the average utility rate for the electricity and natural gas use.

Table B-1 Annual Utility Bills

Utility Bills								
	Electric			Gas				
Month	Cost	kW	$/kW	Cost	MCF	BTU	Therm	$/Therm
January '06	$48.64	654	$0.07	$144.63	10.000	10270000	102.70	$1.41
February '06	$43.58	574	$0.08	$153.77	11.200	11502400	115.02	$1.34
March '06	$50.52	602	$0.08	$104.98	7.800	8010600	80.11	$1.31
April '06	$44.59	489	$0.09	$31.32	1.800	1848600	18.49	$1.69
May '06	$52.09	536	$0.10	$33.16	2.000	2054000	20.54	$1.61
June '06	$94.06	1183	$0.08	$14.96	0.500	513500	5.14	$2.91
July '06	$122.65	1317	$0.08	$17.21	0.700	718900	7.19	$2.39
August '06	$132.52	1475	$0.08	$17.13	0.700	718900	7.19	$2.38
September '06	$73.32	926	$0.08	$16.57	0.600	616200	6.16	$2.69
October '06	$64.55	844	$0.08	$39.96	2.600	2670200	26.70	$1.50
November '06	$47.57	595	$0.08	$61.58	6.200	6367400	63.67	$0.97
December '06	$52.71	722	$0.07	$134.25	11.300	11605100	116.05	$1.16
January '07	$48.65	618	$0.08	$177.08	14.200	14583400	145.83	$1.21
February '07	$50.79	642	$0.08	$207.17	16.400	16842800	168.43	$1.23
March '07	$41.26	482	$0.09	$84.66	6.100	6264700	62.65	$1.35
April '07	$44.31	553	$0.08	$70.92	4.600	4724200	47.24	$1.50
May '07	$59.44	740	$0.08	$26.25	1.100	1129700	11.30	$2.32
June '07	$86.78	1079	$0.08	$21.42	0.700	718900	7.19	$2.98
July '07	$104.21	1208	$0.09	$20.22	0.600	616200	6.16	$3.28
August '07	$135.80	1358	$0.08	$21.34	0.700	718900	7.19	$2.97
September '07	$95.63	1244	$0.08	$19.73	0.600	616200	6.16	$3.20
October '07	$56.30	838	$0.07	$24.79	1.100	1129700	11.30	$2.19
November '07	$50.62	725	$0.07	$78.31	6.300	6470100	64.70	$1.21
December '07	$49.66	655	$0.08	$167.94	14.100	14480700	144.81	$1.16

Table B-2 Annual Utility Bills Continued

Utility Bills								
	Electric			Gas				
Month	Cost	kW	$/kW	Cost	MCF	BTU	Therm	$/Therm
January '08	$50.69	668	$0.08	$198.36	16.700	17150900	171.51	$1.16
February '08	$46.27	605	$0.08	$176.36	14.800	15199600	152.00	$1.16
March '08	$43.82	523	$0.08	$122.38	9.200	9448400	94.48	$1.30
April '08	$49.17	529	$0.09	$93.99	6.000	6162000	61.62	$1.53
May '08	$40.40	431	$0.09	$37.24	1.900	1951300	19.51	$1.91
June '08	$62.68	660	$0.09	$22.69	0.600	616200	6.16	$3.68
July '08	$122.35	1261	$0.10	$23.63	0.700	718900	7.19	$3.29
August '08	$124.04	1144	$0.11	$22.33	0.600	616200	6.16	$3.62
September '08	$93.52	1061	$0.09	$23.08	0.700	718900	7.19	$3.21
October '08	$164.00	795	$0.21	$37.76	1.800	1848600	18.49	$2.04
November '08	$52.74	585	$0.09	$84.88	7.000	7189000	71.89	$1.18
December '08	$63.49	765	$0.08	$168.09	16.700	17150900	171.51	$0.98
January '09	$56.38	642	$0.09	$181.07	15.500	15918500	159.19	$1.14
February '09	$52.17	520	$0.10	$133.64	11.200	11502400	115.02	$1.16
March '09	$48.78	467	$0.10	$89.68	8.200	8421400	84.21	$1.06
April '09	$51.99	473	$0.11	$75.23	6.500	6675500	66.76	$1.13
May '09	$55.74	515	$0.11	$25.20	1.300	1335100	13.35	$1.89
June '09	$95.33	924	$0.10	$19.45	0.700	718900	7.19	$2.71
July '09	$119.98	1193	$0.10	$18.06	0.500	513500	5.14	$3.52
August '09	$127.88	1268	$0.10	$18.62	0.600	616200	6.16	$3.02
September '09	$96.31	969	$0.10	$17.70	0.500	513500	5.14	$3.45
October '09	$60.72	593	$0.10	$41.20	3.300	3389100	33.89	$1.22
November '09	$54.13	514	$0.11	$55.56	5.400	5545800	55.46	$1.00
December '09	$70.25	704	$0.10	$158.79	16.400	16842800	168.43	$0.94

Table B-3 Annual Utility Bills Continued

Utility Bills								
	Electric			Gas				
Month	Cost	kW	$/kW	Cost	MCF	BTU	Therm	$/Therm
January '10	$61.87	605	$0.10	$167.05	16.900	17356300	173.56	$0.96
February '10	$62.32	588	$0.11	$168.82	15.400	15815800	158.16	$1.07
March '10	$55.30	521	$0.11	$99.70	8.700	8934900	89.35	$1.12
April '10	$51.76	464	$0.11	$37.01	2.300	2362100	23.62	$1.57
May '10	$50.03	445	$0.11	$30.47	1.800	1848600	18.49	$1.65
June '10	$118.65	1163	$0.10	$19.39	0.600	616200	6.16	$3.15
July '10	$134.25	1248	$0.11	$18.42	0.500	513500	5.14	$3.59
August '10	$168.16	1488	$0.11	$20.32	0.700	718900	7.19	$2.83
September '10	$114.90	1094	$0.11	$20.24	0.700	718900	7.19	$2.82
October '10	$81.46	795	$0.10	$22.98	1.100	1129700	11.30	$2.03
November '10	$86.03	843	$0.10	$53.15	5.100	5237700	52.38	$1.01
December '10	$80.43	781	$0.10	$131.18	16.300	16740100	167.40	$0.78
January '11	$72.07	681	$0.11	$154.84	17.200	17664400	176.64	$0.88
February '11	$69.56	654	$0.11	$129.60	14.500	14891500	148.92	$0.87
March '11	$61.76	569	$0.11	$98.81	10.100	10372700	103.73	$0.95
April '11	$56.76	493	$0.12	$52.76	4.600	4724200	47.24	$1.12
May '11	$62.33	549	$0.11	$32.15	2.100	2156700	21.57	$1.49
June '11	$105.62	985	$0.11	$20.05	0.700	718900	7.19	$2.79
July '11	$179.86	1344	$0.11	$19.19	0.600	616200	6.16	$3.11
August '11	$165.49	1514	$0.11	$19.23	0.600	616200	6.16	$3.12
September '11	$104.51	967	$0.11	$20.18	0.700	718900	7.19	$2.81
October '11	$81.98	766	$0.11	$29.41	1.800	1848600	18.49	$1.59
November '11	$74.37	684	$0.11	$66.48	6.600	6778200	67.78	$0.98

Table B-4 Average Utility Bill and Average Charge Rates

	Electric			Gas				
Average	Cost	kW	$/kW	Cost	MCF	BTU	Therm	$/Therm
January	$56.38	644.67	$0.09	$170.51	15.08	15,090,583	150.91	$1.10
February	$54.12	597.17	$0.09	$161.56	13.92	13,492,417	134.92	$1.20
March	$50.24	527.33	$0.10	$100.04	8.35	8,575,450	85.75	$1.17
April	$49.76	500.17	$0.10	$60.21	4.30	4,416,100	44.16	$1.36
May	$53.34	536.00	$0.10	$30.75	1.70	1,745,900	17.46	$1.76
June	$93.85	999.00	$0.09	$19.66	0.63	650,433	6.50	$3.02
July	$130.55	1,261.83	$0.10	$19.46	0.60	616,200	6.16	$3.16
August	$142.32	1,374.50	$0.10	$19.83	0.65	667,550	6.68	$2.97
September	$96.37	1,043.50	$0.09	$19.58	0.63	650,433	6.50	$3.01
October	$84.84	771.83	$0.11	$32.68	1.95	2,002,650	20.03	$1.63
November	$60.91	657.67	$0.09	$66.66	6.10	6,664,700	66.65	$1.00
December	$63.31	725.40	$0.09	$152.05	14.96	14,163,920	141.64	$1.07
Annual Charge=	$935.98		$0.095	$852.97	=Annual Charge			$1.21

Diversifying the Interior Lighting

The process for lowering the lighting power densities throughout the residence is discussed in Chapter 3. The number of hours in a year that a light was on and being used was estimated by polling the occupants. The occupants stated the number of hours they anticipated using the lighting in various rooms of the house and that number was used to estimate the annual lighting power density based on total hours of use. Room that were used most often with the lights on still saw a significant reduction in lighting use because residential lighting is much different than commercial lighting. In residences, occupants are not home during the day, turn light off when exiting a room, utilize daylighting, or conserve energy by keeping lights off. Rooms that were not used often had to have their lighting reduced to where the lighting in such spaces was only on about 1% of the time. The data and assumptions made can be found in Table B-5.

Table B-6 displays the average LPD for each area type according to the room types offered by the eQuest model. The calculated LPD average will then be multiplied by the area allocation determined by the model and area type to get the total interior lighting power anticipated in the residence. These numbers are very low because of the low lighting use and therefore lead to a low energy impact.

Table B-5 Interior Lighting Diversification

Room Number	Room Name	Area	Watts	LPD	Diversification Applied	Hrs/Year	Hrs/Day	Category	Notes
001	Corridor	33.25	40	0.008	0.70%	61	0.167	Residential	Half incandescent and half flourescent; If occupants are downstairs, lights most liekly on
002	Spare Closet	22.15	40	0.019	1.04%	91	0.250	Storage	Scarcely Used
003	Spare Bedroom	181.25	80	0.001	0.23%	20	-	Residential	Rarely used
004	Spare Bathroom	52.50	160	0.021	0.70%	61	0.167	Restroom	Bathroom lights are only on when used, which is not very often
005	Closet	7.72	40	0.030	0.57%	50	-	Storage	Scarcely Used
006	Lounge	205.25	160	0.009	1.14%	100	-	Residential	Flourescent
007	Living Room	467.54	320	0.086	12.50%	1096	3.000	Residential	Flourescent
008	Mech	245.75	160	0.004	0.57%	50	-	Mech/Elec Room	Flourescent; used for storage and not frequented at night
009	Fitness	180.84	160	0.018	2.08%	183	0.500	Residential	Flourescent
010	Laundry	227.00	160	0.008	1.14%	100	-	Laundry	Not often used at night
101	Vestibule	104.00	80	0.000	0.00%	0	0.000	Corridor	Only on at night when guests are at the door
102	Kitchen	225.00	160	0.119	16.67%	1461	4.000	Kitchen	
103	Pantry	12.00	40	0.000	0.00%	0	0.000	Storage	Scarcely Used
104	Sun Room	170.33	135	0.033	4.17%	365	1.000	Residential	Daylight utilized when available.
105	Dining Room	158.34	192	0.007	0.57%	50	-	Residential	
106	Living Room	342.32	170	0.006	1.14%	100	0.000	Residential	
107	Master Bathroom	52.28	100	0.159	8.33%	730	2.000	Restroom	Both levels of switching are unlikely to be used at one time. One level controls the shower lights and the other level controls the mirror.
108	Master Bedroom	172.00	80	0.019	4.17%	365	1.000	Residential	
109	Master Closet	30.00	40	0.014	1.04%	91	0.250	Storage	
110	Spare Closet	28.90	40	0.000	0.00%	0	0.000	Storage	Scarcely Used
111	Spare Bedroom	150.00	160	0.006	0.57%	50	-	Residential	Rarely used
112	Spare Bathroom	68.75	160	0.024	1.04%	91	0.250	Restroom	Bathroom lights are only on when it is in use, which is not very often. Mirror use reserved for Master Bathroom.
113	Den	121.00	80	0.083	12.50%	1096	3.000	Residential	
114	Den Closet	21.00	40	0.000	0.00%	0	0.000	Storage	Scarcely Used
115	Corridor	70.83	80	0.010	0.86%	75	-	Corridor	Lights typically kept off in the corridor
116	Stair	49.80	40	0.008	1.04%	91	0.250	Corridor	
	Garage	4053.00	120	0.001	4.17%	365	1.000	Garage	

Table B-6 Interior LPD Averages per Area Type

Floor	Category	Average LPD
Lower Floor	Residential	0.043
	Storage	0.000
	Laundry	0.008
	Restroom	0.021
	Mech/Elec	0.000
First Floor	Residential	0.021
	Storage	0.005
	Restroom	0.083
	Kitchen	0.119
	Corridor	0.005

Appendix C - Improvement Data

This appendix will show the documented results of the improvement analysis performed on the original residence and as a result of its energy model. Improvements or alterations were made to the above-grade walls, below-grade walls, roof insulation, roofing material, glass, system efficiency, and thermostatic setpoints. The results were recorded in several spreadsheets in terms of annual energy savings and paybacks. Improvements were made to the original residence (built in 1970) and to a proposed residence being built to the minimum requirements of ASHRAE 90.2.

Table C-1 Above Grade Wall Improvements

Envelope	Option	Enevelope Construction	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Utility Bill	Energy Bill Improveme	Insulation Cost	Framing	Initial Cost	Cost Difference	Payback	ROI	Source	Notes
Above-Grade Wall	Original Wall	Original Above-Grade Wall Insulation, 2 x 4 studs, 16 in. o.c., R-15 batt	15.0	0.0	42.0	$1,789	-	$575	$716	$1,291	-	-	-	Chuck	Loose-fill batt, Wooden plates: 12' #2 & Better, Studs: 8' #2 & better (Means Price: $650)
	A	2 x 4 studs, R-15 batt, R-5 3/4 in. fiber board sheathing	20.0	0.0	42.0	$1,737	$52	$1,196	$716	$1,912	$621	11.95	0.08	Menards	Owens Corning FOAMULAR Rigid Sheathing, R4, 4 x 8 panels. $14.46
	B	2 x 4 studs, R-15 batt, R-5 1 in. polystyrene	20.0	0.0	42.0	$1,735	$54	$1,281	$716	$1,997	$706	13.08	0.08	Menards	Owens Corning FOAMULAR 150, R-5, 4' x 8' panels. $14.64 each
	C	2 x 4 studs, R-15 batt, R-7.5 1.5 in. polystyrene	22.5	0.0	42.0	$1,729	$60	$1,539	$716	$2,256	$964	16.07	0.06	Menards	Owens Corning FOAMULAR 150, R-7.5, 4' x 8' panels. $22.44 each
	D	2 x 4 studs, R-15 batt, R-10 2 in. polystyrene	25.0	0.0	42.0	$1,716	$73	$1,860	$716	$2,576	$1,285	17.61	0.06	Menards	Owens Corning FOAMULAR 150, R-10, 4' x 8' panels. $29.90 each
	E	2 x 4 studs, R-15 batt, R-15 3 in. polystyrene	30.0	0.0	42.0	$1,685	$104	$2,464	$716	$3,180	$1,889	18.16	0.06	Menards	Owens Corning FOAMULAR 150, R-15, 4' x 8' panels. $43.93 each
	F	2 x 6 Studs, R-19 Batt	19.0	0.0	42.0	$1,760	$29	$625	$1,115	$1,740	$449	15.48	0.06	Menards	Just loose-fill batt
	G	2 x 6 Studs, R-21 Batt	21.0	0.0	42.0	$1,744	$45	$834	$1,115	$1,950	$659	14.63	0.07	Home Depot	Just loose-fill batt (Means Price: $1021)
	H	2 x 6 Studs, R-15 Batt, 1 in. polystyrene, R-5	20.0	0.0	42.0	$1,733	$56	$1,541	$1,115	$2,657	$1,365	24.38	0.04	Menards	Just loose-fill batt (Means Price: $1021)
	I	2 x 6 Studs, R-21 Batt, 1 in. polystyrene, R-5	26.0	0.0	42.0	$1,705	$84	$1,464	$1,115	$2,579	$1,288	15.33	0.07	Menards	Owens Corning FOAMULAR 150, R-5, 4' x 8' panels. $14.64 each
	J	2 x 6 Studs, R-21 Batt, 1.5 in. polystyrene, R-7.5	28.5	0.0	42.0	$1,701	$88	$1,799	$1,115	$2,915	$1,623	18.45	0.05	Menards	Owens Corning FOAMULAR 150, R-7.5, 4' x 8' panels. $22.44 each
	K	2 x 6 Studs, R-21 Batt, 2 in. polystyrene, R-10	31.0	0.0	42.0	$1,686	$103	$2,120	$1,115	$3,235	$1,944	18.88	0.05	Menards	Owens Corning FOAMULAR 150, R-10, 4' x 8' panels. $29.90 each
	L	2 x 6 Studs, R-21 Batt, 3 in. polystyrene, R-15	36.0	0.0	42.0	$1,671	$118	$2,981	$1,115	$4,097	$2,806	23.78	0.04	Menards	Owens Corning FOAMULAR 150, R-15, 4' x 8' panels. $43.93 each
	M	2 x 4 studs, R-15 batt, R-5 1 in. polystyrene, ASHRAE minimum clg. Insulation	20.0	0.0	38.0	$1,742	$47	$1,281	$716	$1,997	$706	15.03	0.07	Menards	Owens Corning FOAMULAR 150, R5, 4' x 8' panels. $14.64 each
	N	2 x 4 studs, R-15 batt, R-7.5 1.5 in. polystyrene, ASHRAE minimum clg. Insulation	22.5	0.0	38.0	$1,731	$58	$1,539	$716	$2,255	$964	16.63	0.06	Menards	Owens Corning FOAMULAR 150, R-7.5, 4' x 8' panels. $22.44 each
	O	2 x 4 studs, R-15 batt, R-10 2 in. polystyrene, ASHRAE minimum clg. Insulation	25.0	0.0	38.0	$1,716	$73	$1,860	$716	$2,576	$1,285	17.61	0.06	Menards	Owens Corning FOAMULAR 150, R-10, 4' x 8' panels. $29.90 each
	P	2 x 4 studs, R-15 batt, R-15 3 in. polystyrene, ASHRAE minimum clg. Insulation	30.0	0.0	38.0	$1,695	$94	$2,464	$716	$3,180	$1,889	20.09	0.05	Menards	Owens Corning FOAMULAR 150, R-15, 4' x 8' panels. $43.93 each
	Q	2 x 6 Studs, R-21 Batt, 1 in. polystyrene, R-5, ASHRAE minimum clg. Insulation	26.0	0.0	38.0	$1,721	$68	$1,464	$1,115	$2,579	$1,288	18.94	0.05	Menards	Owens Corning FOAMULAR 150, R5, 4' x 8' panels. $14.64 each
	R	2 x 6 Studs, R-21 Batt, 1.5 in. polystyrene, R-7.5, ASHRAE minimum clg. Insulation	28.5	0.0	38.0	$1,706	$83	$1,799	$1,115	$2,914	$1,623	19.56	0.05	Menards	Owens Corning FOAMULAR 150, R-7.5, 4' x 8' panels. $22.44 each
	S	2 x 6 Studs, R-21 Batt, 2 in. polystyrene, R-10, ASHRAE minimum clg. Insulation	31.0	0.0	38.0	$1,698	$91	$2,120	$1,115	$3,235	$1,944	21.36	0.05	Menards	Owens Corning FOAMULAR 150, R-10, 4' x 8' panels. $29.90 each
	T	2 x 6 Studs, R-21 Batt, 3 in. polystyrene, R-15, ASHRAE minimum clg. Insulation	36.0	0.0	38.0	$1,675	$114	$2,981	$1,115	$4,096	$2,805	24.61	0.04	Menards	Owens Corning FOAMULAR 150, R-15, 4' x 8' panels. $43.93 each

Table C-2 Above-Grade Wall Improvements Continued

Envelope	Option	Enevelope Construction	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Utility Bill	Energy Bill Improveme	Insulation Cost	Framing	Initial Cost	Cost Difference	Payback	ROI	Source	Notes
Above-Grade Wall	Original Wall	Original Above-Grade Wall Insulation, 2 x 4 studs, 16 in. o.c., R-15 batt	15.0	0.0	42.0	$1,789	-	$575	$716	$1,291	-	-	-	Owner	Loose-fill batt, Wooden plates: 12' #2 & Better, Studs: 8' #2 & better (Means Price: $650)
	ASHRAE A	2 x 4 studs, ASHRAE 90.2 Baseline incorporated (R-5 continuous insulation)	20.0	0.0	38.0	$2,044	-$255	$1,204	$716	$1,920	-	-	-	Menards	Owens Corning FOAMULAR 150, R5, 4' x 8' panels. $14.64 each
	ASHRAE B	2 x 6 studs, ASHRAE 90.2 Baseline incorporated (R-5 continuous insulation)	20.0	0.0	38.0	$2,033	-$244	$834	$1,115	$1,949	$29	-0.12	-8.42	Menards	Owens Corning FOAMULAR 150, R5, 4' x 8' panels. $14.64 each
	ASHRAE C	2 x 4 studs (ASHRAE), R-15 batt, R-7.5 1.5 in. polystyrene	22.5	0.0	38.0	$2,027	$17	$1,539	$716	$2,256	$335	19.73	0.05	Menards	Owens Corning FOAMULAR 150, R-7.5, 4' x 8' panels. $22.44 each
	ASHRAE D	2 x 4 studs (ASHRAE), R-15 batt, R-10 2 in. polystyrene	25.0	0.0	38.0	$2,013	$31	$1,860	$716	$2,576	$656	21.17	0.05	Menards	Owens Corning FOAMULAR 150, R-10, 4' x 8' panels. $29.90 each
	ASHRAE E	2 x 4 studs (ASHRAE), R-15 batt, R-15 3 in. polystyrene	30.0	0.0	38.0	$1,988	$56	$2,464	$716	$3,180	$1,259	22.49	0.04	Menards	Owens Corning FOAMULAR 150, R-15, 4' x 8' panels. $43.93 each
	ASHRAE F	2 x 6 studs (ASHRAE), R-5 1 in. polystyrene	26.0	0.0	38.0	$2,016	$28	$1,464	$1,115	$2,579	$659	23.54	0.04	Menards	Owens Corning FOAMULAR 150, R-5, 4' x 8' panels. $14.64 each
	ASHRAE G	2 x 6 studs (ASHRAE), R-7.5 1.5 in. polystyrene	28.5	0.0	38.0	$1,998	$46	$1,799	$1,115	$2,915	$994	21.62	0.05	Menards	Owens Corning FOAMULAR 150, R-7.5, 4' x 8' panels. $22.44 each
	ASHRAE H	2 x 6 studs (ASHRAE), R-10 2 in. polystyrene	31.0	0.0	38.0	$1,988	$56	$2,120	$1,115	$3,235	$1,315	23.49	0.04	Menards	Owens Corning FOAMULAR 150, R-10, 4' x 8' panels. $29.90 each
	ASHRAE I	2 x 6 studs (ASHRAE), R-15 3 in. polystyrene	36.0	0.0	38.0	$1,975	$69	$2,723	$1,115	$3,839	$1,918	27.80	0.04	Menards	Owens Corning FOAMULAR 150, R-15, 4' x 8' panels. $43.93 each

Table C-3 Below-Grade Wall Improvements

Option	System Details	Cooling SEER	Heating AFUE	Utility Bill	Energy Bill Improvement	Initial Cost	Cost Difference	Payback	Source	Notes
Original	Original cooling SEER	13.0	94.0%	$1,789	-	$2,347	-	-	Owner	3-ton furnace with DX cooling
A	Improve SEER to 14	14.0	94.0%	$1,775	$14	$2,642	$295	21.07	Lennox	3-ton furnace with DX cooling
B	Improve SEER to 16	16.0	94.0%	$1,753	$36	$3,073	$726	20.17	Lennox	3-ton furnace with DX cooling
C	Improve SEER to 21	21.0	94.0%	$1,717	$72	$4,175	$1,828	25.39	Lennox	3-ton furnace with DX cooling
D	Improve AFUE to 98%	13.0	98.0%	$1,755	$34	$3,215	$2,295	67.50	Lennox	3-ton furnace with DX cooling
Older Homes	Low SEER	8.0	94.0%	$1,907	-$118			0.00		3-ton furnace with DX cooling
	Low SEER	10.0	94.0%	$1,846	-$57			0.00		3-ton furnace with DX cooling
	Low SEER	11.0	94.0%	$1,823	-$34			0.00		3-ton furnace with DX cooling
	Low SEER	12.0	94.0%	$1,805	-$16			0.00		3-ton furnace with DX cooling
	Low AFUE	13.0	80.0%	$1,941	-$152	$2,045	$1,127	-7.41		3-ton furnace with DX cooling
ASHRAE	Original cooling EER	9.3*	80.0%	$2,044	-	$2,045	-	-	Lennox	
ASHRAE	Improve SEER to 14	14.0	80.0%	$1,990	$54	$2,340	$295	5.46	Lennox	DX = $1422, Furnace = $619
ASHRAE	Improve SEER to 16	16.0	80.0%	$1,967	$77	$2,771	$726	9.43	Lennox	DX = $1853, Furnace = $620
ASHRAE	Improve SEER to 21	21.0	80.0%	$1,931	$113	$3,873	$1,828	16.18	Lennox	DX = $2955, Furnace = $621
ASHRAE	Improve SEER to 14	14.0	94.0%	$1,871	$173	$2,642	$597	3.45	Lennox	DX = $1422, Furnace = $920
ASHRAE	Improve SEER to 16	16.0	94.0%	$1,848	$196	$3,073	$1,028	5.24	Lennox	DX = $1853, Furnace = $921
ASHRAE	Improve SEER to 21	21.0	94.0%	$1,812	$232	$4,175	$2,130	9.18	Lennox	DX = $2955, Furnace = $922

Table C-4 Above-Ceiling Insulation Improvements

Option	Enevelope Construction	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Utility Bill	Energy Bill Improvement	Insulation Cost	Initial Cost	Cost Difference	Payback	ROI	Source	Notes
Original	Original above-ceiling insulation, loose-fill batt	15.0	0.0	42.0	$1,789	-	$1,023	$0	-	-	-		
A	Increase ceiling insulation R-value by 1	15.0	0.0	43.0	$1,787	$2	$1,040	$1,040	$17	8.53	0.12	RSMeans	Blown Insulation for ceilings, with open access $0.60/s.f.
B	Increase ceiling insulation R-value by 7	15.0	0.0	49.0	$1,784	$5	$1,057	$1,057	$34	6.82	0.15	RSMeans	Blown Insulation for ceilings, with open access $0.61/s.f.
C	Increase ceiling insulation R-value by 18	15.0	0.0	60.0	$1,776	$13	$1,194	$1,194	$171	13.12	0.08	RSMeans	Blown Insulation for ceilings, with open access $0.70/s.f.
Older Homes	Remove ceiling insulation	15.0	0.0	0.0	$2,343	-$554	$0	$0	-$1,023	-	0.54		
	R-11 batt insulation	15.0	0.0	11.0	$1,914	-$125	$256	$256	-$767	6.14	0.16	RSMeans	Blown Insulation for ceilings, with open access $0.15/s.f.
	R-13 batt insulation	15.0	0.0	13.0	$1,882	-$93	$290	$290	-$733	7.89	0.13	RSMeans	Blown Insulation for ceilings, with open access $0.17/s.f.
	R-21 batt insulation	15.0	0.0	21.0	$1,838	-$49	$512	$512	-$512	10.44	0.10	RSMeans	Blown Insulation for ceilings, with open access $0.30/s.f.
	R-30 batt insulation	15.0	0.0	30.0	$1,809	-$20	$850	$850	-$174	8.68	0.12	Menards	R-30 for $31.47 at 65 s.f. (Means Price: $750 at $0.44/s.f.)
ASHRAE A	R-38 required	20.0	0.0	38.0	$2,044	-	$955	$955	-	-	-	RSMeans	Blown Insulation for ceilings, with open access $0.56/s.f.
ASHRAE B	Increase ceiling insulation R-value by 7 (ASHRAE)	20.0	0.0	45.0	$2,034	$10	$989	$989	$34	3.41	0.29	RSMeans	Blown Insulation for ceilings, with open access $0.58/s.f.
ASHRAE C	Increase ceiling insulation R-value by 11 (ASHRAE)	20.0	0.0	49.0	$2,030	$14	$1,057	$1,057	$102	7.31	0.14	RSMeans	Blown Insulation for ceilings, with open access $0.62/s.f.
ASHRAE D	Increase ceiling insulation R-value by 22 (ASHRAE)	20.0	0.0	60.0	$2,021	$23	$1,194	$1,194	$239	10.38	0.10	RSMeans	Blown Insulation for ceilings, with open access $0.70/s.f.

Table C-5 Roofing Material Improvements

Option	Roofing Material	Finsih	Color	ABS	Utility Bill	Energy Bill Improveme	Source	Notes
Original	Original roofing material color	Shingles	Med/Light Brown	0.6	$1,789	-	eQuest	
A	Altered shingle color	Shingles	Dark Brown	0.9	$1,787	$2	eQuest	Cooling increases, but heating decreases
B	Altered shingle color	Shingles	'Dark'	0.9	$1,787	$2	eQuest	Cooling increases, but heating decreases
C	Altered shingle color	Shingles	'Medium'	0.6	$1,792	-$3	eQuest	Cooling decreases, but heating increases
D	Altered shingle color	Shingles	'Light'	0.4	$1,795	-$6	eQuest	Cooling decreases, but heating increases
E	Altered shingle color	Shingles	Flat Black	-	$1,786	$3	eQuest	Cooling increases, heating decreases
F	Altered shingle color	Shingles	Light Green	-	$1,794	-$5	eQuest	Cooling decreases, but heating increases
G	Altered shingle color	Shingles	Rust	-	$1,789	$0	eQuest	Same

Option	No. of Panes	Window Construction	Shading Coefficient	Visible Transmittance	Casement U-Value	Double-Hung U-Value	First Floor U-Value	Basement U-Value	Utility Bill	Energy Bill Improvement	Initial Cost	Cost Increase	Payback	Source	Notes
Original A	1	Single Pane + Storm, Clear	0.84	0.81	-	-	0.50	0.81	$1,788	-	$6,520	-	-	ACCA	All non-tempered, prices estimated from Chuck
Original B	1	Single Pane + Storm, Clear	0.35	0.81	-	-	0.50	0.81	$1,789	-	$6,520	-	-	ACCA	
A	1	Single Pane + Storm, Low e	0.35	0.81	-	-	0.35	0.35	$1,739	$50	$6,700	-	-	ACCA	
B	2	Clear Pane + Low e Pane	0.35	0.81	-	-	0.38	0.38	$1,745	-	$9,444	$0	-	Jeld-Wen	Casement = $231.30, D-H = $291.84, Sliding = $413.48
C	2	Shade between 2 panes	0.35	0.81	-	-	0.28	0.28	$1,709	$36	$9,444	$0	0.00	ACCA	Internal blinds removed from model
D	3	Triple pane, 1/2" gap	0.35	0.81	-	-	0.27	0.27	$1,704	$41	$13,798	$4,354	106.20	Eagle	Casement = $552.52, D-H = $469.35, Sliding = $495.85
E	2	11/16" Advanced Low-e IG with Argon	0.35	0.51	0.29	0.30	0.295	0.300	$1,717	$28	$11,765	$2,321	82.89	Pella	Glass thickness differed by .5 mm, energy star construction u-value
F	2	11/16" SunDefense Low-e IG with Argon	0.35	0.47	0.29	0.29	0.290	0.300	$1,715	$30	$12,326	$2,882	96.07	Pella	
G	2	11/16" SunDefense Dual Low-e IG with Argon	0.35	0.44	0.26	0.26	0.260	0.300	$1,706	$39	$12,862	$3,418	87.64	Pella	
H	2	Tinted; 11/16" Bronze Advanced Low-e IG w/ Argon	0.35	0.33	0.30	0.30	0.300	0.300	$1,719	$26	$12,326	$2,882	110.85	Pella	
I	2	11/16" Gray Advanced Low-e IG w/Argon	0.35	0.29	0.30	0.30	0.300	0.300	$1,719	$26	$12,326	$2,882	110.85	Pella	
J	2	A-Series, High-Performance Low-e 4 with Argon	0.35	0.71	0.25	0.25	0.250	0.300	$1,702	$43	$17,890	$8,446	196.42	Andersen	Center of glass, 200 series sliding (VT=0.55) for basement windows
K	2	400 Series Woodwright® Insert Replacement Windows, HP Low-e4	0.35	0.54	0.28	0.30	0.290	0.300	$1,715	$30	$12,932	$3,488	116.27	Andersen	Center of glass, 400 series double-hung, 400 series casement, 200 series sliding
L	2	400 Series Woodwright® Insert Replacement Windows, HP Low-e4 Sun	0.35	0.30	0.28	0.30	0.290	0.300	$1,715	$30	$12,932	$3,488	116.27	Andersen	Center of glass, 400 series double-hung, 400 series casement, 200 series sliding
M	2	400 Series Woodwright® Insert Replacement Windows, HP Low-e4 SmartSun	0.35	0.49	0.27	0.29	0.280	0.300	$1,712	$33	$12,932	$3,488	105.70	Andersen	Center of glass, 400 series double-hung, 400 series casement, 200 series sliding
N	2	200 Series Tilt-Wash Double-Hung Windows, 400 Series Casement, Low-e	0.35	0.55	0.28	0.30	0.290	0.300	$1,715	$30	$9,522	$78	2.60	Andersen	Center of glass, 200 series double-hung, 400 series casement, 200 series sliding
O	2	200 Series Tilt-Wash Double-Hung Windows, 400 Series Casement, Low-e Smartsun	0.35	0.49	0.27	0.29	0.280	0.300	$1,712	$33	$9,522	$78	2.36	Andersen	Center of glass, 200 series double-hung, 400 series casement, 200 series sliding
P	2	200 Series Narroline Double-Hung Windows, 400 Series Casement, Low-e	0.35	0.55	0.28	0.30	0.290	0.300	$1,715	$30	$9,445	$1	0.03	Andersen	Center of glass, 200 series double-hung, 400 series casement, 200 series sliding
Q	2	200 Series Narroline Double-Hung Windows, 400 Series Casement, Low-e Sun	0.35	0.31	0.28	0.30	0.290	0.300	$1,715	$30	$9,445	$1	0.03	Andersen	Center of glass, 200 series double-hung, 400 series casement, 200 series sliding
R	2	Wood Ultimate 11/16" IG - LoE - 272 - Argon	0.35	0.50	0.28	0.29	0.285	0.280	$1,714	$31		-$9,444	-304.65	Marvin	Center of glass, Wood Ultimate Dbl-Hung, Casement, & Glider for basement windows (VT=0.41)
S	2	Wood Ultimate 11/16" IG - LoE - 366 - Argon	0.35	0.44	0.27	0.28	0.275	0.280	$1,709	$36		-$9,444	-262.33	Marvin	Center of glass, Wood Ultimate Dbl-Hung, Casement, & Glider for basement windows
T	3	Wood Ultimate 7/8" IG - Tri-pane LoE - 179 - Argon	0.35	0.48	0.23	0.25	0.240	0.280	$1,694	$51		-$9,444	-185.18	Marvin	Center of glass, Wood Ultimate Dbl-Hung, Casement, & Glider for basement windows
U	3	Wood Ultimate 7/8" IG - Tri-pane LoE - 272 - Argon	0.35	0.39	0.20	0.22	0.210	0.280	$1,684	$61		-$9,444	-154.82	Marvin	Center of glass, Wood Ultimate Dbl-Hung, Casement, & Glider for basement windows

Table C-6 Glass Improvements

Option	No. of Panes	Window Construction	Shading Coefficient	Visible Transmittance	Casement U-Value	Double-Hung U-Value	First Floor U-Value	Basement U-Value	Utility Bill	Energy Bill Improvement	Initial Cost	Cost Increase	Payback	Source	Notes
Orig.	1	Single Pane + Storm, Clear	0.35	0.81	-	-	0.50	0.81	$1,789	-	$6,520	-	-	ACCA	
A	2	Clear Pane + Low e Pane	0.35	0.81	-	-	0.38	0.38	$1,745	-	$9,444	$0	-	Jeld-Wen	Casement = $231.30, D-H = $291.84, Sliding = $413.48
B	2	ASHRAE Baseline	0.35	0.81	-	-	0.35	0.35	$2,044	-	-	-	-	-	
C	2	ASHRAE Baseline, Clear Pane + Low e Pane	0.35	0.81	-	-	0.38	0.38	$2,055	-$11	$7,252	-	-	Jeld-Wen	Casement = $231.30, D-H = $291.84, Sliding = $413.48
E	3	ASHRAE Baseline, Triple pane, 1/2" gap	0.35	0.81	0.27	0.27	0.27	0.27	$2,014	$30	$14,386	$4,942	164.72	Eagle	Casement = $552.52, D-H = $469.35, Sliding = $495.85
F	2	ASHRAE Baseline, Architect Series 11/16" Advanced Low-e IG with Argon	0.35	0.51	0.29	0.30	0.295	0.300	$2,022	$22	$11,765	$2,321	105.50	Pella	Glass thickness differed by .5 mm, energy star construction u-value
G	2	ASHRAE Baseline, Architect Series 11/16" SunDefense Low-e IG with Argon	0.35	0.47	0.29	0.29	0.290	0.300	$2,021	$23	$12,326	$2,882	125.30	Pella	10/20 Series Sliding Basement Window
H	2	ASHRAE Baseline, Architect Series 11/16" SunDefense Dual Low-e IG with Argon	0.35	0.44	0.26	0.26	0.260	0.300	$2,009	$35	$12,862	$3,418	97.66	Pella	10/20 Series Sliding Basement Window
I	2	ASHRAE Baseline, Architect Series Tinted; 11/16" Bronze Advanced Low-e IG w/ Argon	0.35	0.33	0.30	0.30	0.300	0.300	$2,024	$20	$12,326	$2,882	144.10	Pella	10/20 Series Sliding Basement Window
J	2	ASHRAE Baseline, Architect Series 11/16" Gray Advanced Low-e IG w/Argon	0.35	0.29	0.30	0.30	0.300	0.300	$2,024	$20	$12,326	$2,882	144.10	Pella	10/20 Series Sliding Basement Window
K	2	ASHRAE Baseline, A-Series, High-Performance Low-e 4 with Argon	0.35	0.71	0.25	0.25	0.250	0.300	$2,005	$39	$17,890	$8,446	216.56	Andersen	Center of glass, 200 series sliding (VT=0.55) for basement windows
L	2	ASHRAE Baseline, 400 Series Woodwright® Insert Replacement Windows, HP Low-e4	0.35	0.54	0.28	0.30	0.290	0.300	$2,021	$23	$12,932	$3,488	151.65	Andersen	Center of glass, 400 series double-hung, 400 series casement, 200 series sliding
M	2	ASHRAE Baseline, 400 Series Woodwright® Insert Replacement Windows, HP Low-e4 Sun	0.35	0.30	0.28	0.30	0.290	0.300	$2,021	$23	$12,932	$3,488	151.65	Andersen	Center of glass, 400 series double-hung, 400 series casement, 200 series sliding
N	2	ASHRAE Baseline, 400 Series Woodwright® Insert Replacement Windows, HP Low-e4 SmartSun	0.35	0.49	0.27	0.29	0.280	0.300	$2,017	$27	$12,932	$3,488	129.19	Andersen	Center of glass, 400 series double-hung, 400 series casement, 200 series sliding
O	2	ASHRAE Baseline, 200 Series Tilt-Wash Double-Hung Windows, 400 Series Casement, Low-e	0.35	0.55	0.28	0.30	0.290	0.300	$2,021	$23	$9,522	$78	3.39	Andersen	Center of glass, 200 series double-hung, 400 series casement, 200 series sliding
P	2	ASHRAE Baseline, 200 Series Tilt-Wash Double-Hung Windows, 400 Series Casement, Low-e Smartsun	0.35	0.49	0.27	0.29	0.280	0.300	$2,017	$27	$9,522	$78	2.89	Andersen	Center of glass, 200 series double-hung, 400 series casement, 200 series sliding
Q	2	ASHRAE Baseline, 200 Series Narroline Double-Hung Windows, 400 Series Casement, Low-e	0.35	0.55	0.28	0.30	0.290	0.300	$2,021	$23	$9,445	$1	0.04	Andersen	Center of glass, 200 series double-hung, 400 series casement, 200 series sliding
R	2	ASHRAE Baseline, 200 Series Narroline Double-Hung Windows, 400 Series Casement, Low-e Sun	0.35	0.31	0.28	0.30	0.290	0.300	$2,021	$23	$9,445	$1	0.04	Andersen	Center of glass, 200 series double-hung, 400 series casement, 200 series sliding

Table C-7 Glass Improvements Continued

Table C-8 System Efficiency Improvements

Option	System Details	Cooling SEER	Heating AFUE	Utility Bill	Energy Bill Improvement	Initial Cost	Cost Difference	Payback	Source
Original	Original cooling SEER	13.0	94.0%	$1,789	-	$2,347	-	-	Owner
A	Improve SEER to 14	14.0	94.0%	$1,775	$14	$2,642	$295	21.07	Lennox
B	Improve SEER to 16	16.0	94.0%	$1,753	$36	$3,073	$726	20.17	Lennox
C	Improve SEER to 21	21.0	94.0%	$1,717	$72	$4,175	$1,828	25.39	Lennox
D	Improve AFUE to 98%	13.0	98.0%	$1,755	$34	$3,215	$2,295	67.50	Lennox
Older Homes	Low SEER	8.0	94.0%	$1,907	-$118			0.00	
	Low SEER	10.0	94.0%	$1,846	-$57			0.00	
	Low SEER	11.0	94.0%	$1,823	-$34			0.00	
	Low SEER	12.0	94.0%	$1,805	-$16			0.00	
	Low AFUE	13.0	80.0%	$1,941	-$152	$2,045	$1,127	-7.41	
ASHRAE	Original cooling EER	9.3*	80.0%	$2,044	-	$2,045	-	-	Lennox
ASHRAE	Improve SEER to 14	14.0	80.0%	$1,990	$54	$2,340	$295	5.46	Lennox
ASHRAE	Improve SEER to 16	16.0	80.0%	$1,967	$77	$2,771	$726	9.43	Lennox
ASHRAE	Improve SEER to 21	21.0	80.0%	$1,931	$113	$3,873	$1,828	16.18	Lennox
ASHRAE	Improve SEER to 14	14.0	94.0%	$1,871	$173	$2,642	$597	3.45	Lennox
ASHRAE	Improve SEER to 16	16.0	94.0%	$1,848	$196	$3,073	$1,028	5.24	Lennox
ASHRAE	Improve SEER to 21	21.0	94.0%	$1,812	$232	$4,175	$2,130	9.18	Lennox

Table C-9 Thermostat Alterations

System Details	Cooling Setpoint (°F)	Heating Setpoint (°F)	Utility Bill	Energy Bill Improvement	Source	Notes
Original Cooling & Heating Setpoints	75.0	74.0	$1,789	-		
Increase cooling setpoint by 1	76.0	74.0	$1,798	-$9	eQuest	Cooling decrease, heating increase
Increase cooling setpoint by 2	77.0	74.0	$1,781	$8	eQuest	Cooling decrease, heating increase
Increase cooling setpoint by 3	78.0	74.0	$1,765	$24	eQuest	Cooling decrease, heating increase
Decrease cooling setpoint by 1	74.0	74.0	$1,780	$9	eQuest	Cooling increase, heating decrease
Decrease cooling setpoint by 2	73.0	74.0	$1,773	$16	eQuest	Cooling increase, heating decrease
Decrease cooling setpoint by 3	72.0	74.0	$1,766	$23	eQuest	Cooling increase, heating decrease
Decrease cooling setpoint by 4	71.0	74.0	$1,762	$27	eQuest	Cooling increase, heating decrease
Decrease cooling setpoint by 5	70.0	74.0	$1,759	$30	eQuest	Cooling increase, heating decrease
Decrease heating setpoint by 1	75.0	73.0	$1,773	$16	eQuest	Cooling increase, heating decrease
Decrease heating setpoint by 2	75.0	72.0	$1,731	$58	eQuest	Cooling decrease, heating decrease
Decrease heating setpoint by 3	75.0	71.0	$1,692	$97	eQuest	Cooling decrease, heating decrease
Decrease heating setpoint by 4	75.0	70.0	$1,656	$133	eQuest	Cooling decrease, heating decrease
Decrease heating setpoint by 5	75.0	69.0	$1,623	$166	eQuest	Cooling decrease, heating decrease
Decrease heating setpoint by 6	75.0	68.0	$1,591	$198	eQuest	Cooling decrease, heating decrease
Increase heating setpoint by 1	75.0	75.0	$1,806	-$17	eQuest	Heating increase

Combined Improvements

In some scenarios improvements were compounded. The enhancements that saved the most money, or appeared to have money-saving potential, were combined in the eQuest model and the resulting savings were documented and analyzed. Desirable improvements are marked by quicker payback periods. Every envelope improvement is also compared at 3 different thermostatic setpoints: 72°F, 70°F, and 68°F. The most money can be saved by keeping the heating setpoint as low as possible, but 3 are shown for reference.

Table C-10 Improvement Combinations

Envelope	Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Cooling Setpoint	Heating Setpoint	Utility Bill	Energy Bill Improvement	Initial Cost	Improvement Cost	Cost Difference	Payback	ROI	Notes
All Considerations	2 x 4 studs, R-5 exterior bd. below-grade insulation 8 feet deep	15.0	5.0	30.0	75°F	72°F	$1,651	$138	$2,141	$2,700	$559	4.05	0.25	Does not comply with ASHRAE 90.2
	2 x 4 studs, R-5 exterior bd. below-grade insulation 8 feet deep	15.0	5.0	30.0	75°F	70°F	$1,589	$200	$2,141	$2,700	$559	2.80	0.36	Does not comply with ASHRAE 90.2
	2 x 4 studs, R-5 exterior bd. below-grade insulation 8 feet deep	15.0	5.0	30.0	75°F	68°F	$1,533	$256	$2,141	$2,700	$559	2.18	0.46	Does not comply with ASHRAE 90.2
	2 x 4 studs, R-5 exterior bd. below-grade insulation 8 feet deep, original ceiling insulation	15.0	5.0	42.0	75°F	72°F	$1,633	$156	$2,314	$2,873	$559	3.58	0.28	
	2 x 4 studs, R-5 exterior bd. below-grade insulation 8 feet deep, original ceiling insulation	15.0	5.0	42.0	75°F	70°F	$1,571	$218	$2,314	$2,873	$559	2.56	0.39	
	2 x 4 studs, R-5 exterior bd. below-grade insulation 8 feet deep, original ceiling insulation	15.0	5.0	42.0	75°F	68°F	$1,517	$272	$2,314	$2,873	$559	2.06	0.49	
	2 x 4 studs, R-10 exterior bd. below-grade insulation 8 feet deep, original ceiling insulation	15.0	10.0	42.0	75°F	72°F	$1,603	$186	$2,314	$3,432	$1,118	6.01	0.17	
	2 x 4 studs, R-10 exterior bd. below-grade insulation 8 feet deep, original ceiling insulation	15.0	10.0	42.0	75°F	70°F	$1,545	$244	$2,314	$3,432	$1,118	4.58	0.22	
	2 x 4 studs, R-10 exterior bd. below-grade insulation 8 feet deep, original ceiling insulation	15.0	10.0	42.0	75°F	68°F	$1,494	$295	$2,314	$3,432	$1,118	3.79	0.26	
	2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	75°F	72°F	$1,577	$181	$2,246	$3,511	$1,265	6.99	0.14	R-15 batt, R-5 cont. insulation
	2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	75°F	70°F	$1,519	$239	$2,246	$3,511	$1,265	5.29	0.19	
	2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	75°F	68°F	$1,468	$290	$2,246	$3,511	$1,265	4.36	0.23	
	2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	75°F	72°F	$1,547	$211	$2,246	$4,070	$1,824	8.64	0.12	
	2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	75°F	70°F	$1,493	$265	$2,246	$4,070	$1,824	6.88	0.15	
	2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	75°F	68°F	$1,446	$312	$2,246	$4,070	$1,824	5.85	0.17	
	2 x 4 studs, ASHRAE 90.2 Envelope, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	75°F	72°F	$1,532	$226	$2,246	$4,630	$2,384	10.55	0.09	
	2 x 4 studs, ASHRAE 90.2 Envelope, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	75°F	70°F	$1,480	$278	$2,246	$4,630	$2,384	8.58	0.12	
	2 x 4 studs, ASHRAE 90.2 Envelope, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	75°F	68°F	$1,434	$324	$2,246	$4,630	$2,384	7.36	0.14	
	2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	75°F	72°F	$1,552	$206	$2,246	$4,090	$1,844	8.95	0.11	R-15 batt, R-10 cont. insulation
	2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	75°F	70°F	$1,495	$263	$2,246	$4,090	$1,844	7.01	0.14	R-15 batt, R-10 cont. insulation
	2 x 4 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	75°F	68°F	$1,446	$312	$2,246	$4,090	$1,844	5.91	0.17	R-15 batt, R-10 cont. insulation
	2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	75°F	72°F	$1,522	$236	$2,246	$4,649	$2,403	10.18	0.10	R-15 batt, R-10 cont. insulation
	2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	75°F	70°F	$1,469	$289	$2,246	$4,649	$2,403	8.31	0.12	R-15 batt, R-10 cont. insulation
	2 x 4 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	75°F	68°F	$1,423	$335	$2,246	$4,649	$2,403	7.17	0.14	R-15 batt, R-10 cont. insulation

Table C-11 Improvement Combinations Continued

Envelope	Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Cooling Setpoint	Heating Setpoint	Utility Bill	Energy Bill Improvement	Initial Cost	Improvement Cost	Cost Difference	Payback	ROI	Notes
All Considerations	2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	75°F	72°F	$1,570	$188	$2,246	$4,171	$1,925	10.24	0.10	
	2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	75°F	70°F	$1,515	$243	$2,246	$4,171	$1,925	7.92	0.13	
	2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	75°F	68°F	$1,460	$298	$2,246	$4,171	$1,925	6.46	0.15	
	2 x 6 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	75°F	72°F	$1,540	$218	$2,246	$4,730	$2,484	11.39	0.09	
	2 x 6 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	75°F	70°F	$1,490	$268	$2,246	$4,730	$2,484	9.27	0.11	
	2 x 6 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	75°F	68°F	$1,440	$318	$2,246	$4,730	$2,484	7.81	0.13	
	2 x 6 studs, ASHRAE 90.2 Envelope, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	75°F	72°F	$1,524	$234	$2,246	$5,290	$3,044	13.01	0.08	
	2 x 6 studs, ASHRAE 90.2 Envelope, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	75°F	70°F	$1,475	$283	$2,246	$5,290	$3,044	10.76	0.09	
	2 x 6 studs, ASHRAE 90.2 Envelope, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	75°F	68°F	$1,430	$328	$2,246	$5,290	$3,044	9.28	0.11	
	2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	75°F	72°F	$1,564	$194	$2,246	$4,749	$2,503	12.90	0.08	R-15 batt, R-10 cont. insulation
	2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	75°F	70°F	$1,507	$251	$2,246	$4,749	$2,503	9.97	0.10	R-15 batt, R-10 cont. insulation
	2 x 6 studs, ASHRAE 90.2 Envelope, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	75°F	68°F	$1,456	$302	$2,246	$4,749	$2,503	8.29	0.12	R-15 batt, R-10 cont. insulation
	2 x 6 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	75°F	72°F	$1,534	$224	$2,246	$5,308	$3,062	13.67	0.07	R-15 batt, R-10 cont. insulation
	2 x 6 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	75°F	70°F	$1,481	$277	$2,246	$5,308	$3,062	11.05	0.09	R-15 batt, R-10 cont. insulation
	2 x 6 studs, ASHRAE 90.2 Envelope, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	75°F	68°F	$1,434	$324	$2,246	$5,308	$3,062	9.45	0.11	R-15 batt, R-10 cont. insulation

Table C-12 Improvement Combinations Continued

Envelope	Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Cooling Setpoint	Heating Setpoint	Utility Bill	Energy Bill Improvement	Initial Cost	Improvement Cost	Cost Difference	Payback	ROI	Notes
ASHRAE Considerations	ASHRAE Baseline	20.0	0.0	38.0	75°F	74°F	$2,044	-	$2,952	$0	-	-	-	
	2 x 4 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	75°F	72°F	$1,855	$189	$2,952	$3,511	$559	2.96	0.34	
	2 x 4 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	75°F	70°F	$1,786	$258	$2,952	$3,511	$559	2.17	0.46	
	2 x 4 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	75°F	68°F	$1,726	$318	$2,952	$3,511	$559	1.76	0.57	
	2 x 4 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	75°F	72°F	$1,820	$224	$2,952	$4,070	$1,118	4.99	0.20	
	2 x 4 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	75°F	70°F	$1,757	$287	$2,952	$4,070	$1,118	3.90	0.26	
	2 x 4 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	75°F	68°F	$1,701	$343	$2,952	$4,070	$1,118	3.26	0.31	
	2 x 4 studs, ASHRAE 90.2 Baseline, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	75°F	72°F	$1,803	$241	$2,952	$4,630	$1,678	6.96	0.14	
	2 x 4 studs, ASHRAE 90.2 Baseline, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	75°F	70°F	$1,741	$303	$2,952	$4,630	$1,678	5.54	0.18	
	2 x 4 studs, ASHRAE 90.2 Baseline, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	75°F	68°F	$1,687	$357	$2,952	$4,630	$1,678	4.70	0.21	
	2 x 4 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	75°F	70°F	$1,758	$286	$2,952	$4,090	$1,138	3.98	0.25	
	2 x 4 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	75°F	68°F	$1,701	$343	$2,952	$4,090	$1,138	3.32	0.30	
	2 x 4 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	75°F	70°F	$1,728	$316	$2,952	$4,649	$1,697	5.37	0.19	
	2 x 4 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	75°F	68°F	$1,674	$370	$2,952	$4,649	$1,697	4.59	0.22	
	2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	75°F	72°F	$1,839	$205	$2,952	$4,171	$1,219	5.95	0.17	
	2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	75°F	70°F	$1,772	$272	$2,952	$4,171	$1,219	4.48	0.22	
	2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	20.0	5.0	38.0	75°F	68°F	$1,713	$331	$2,952	$4,171	$1,219	3.68	0.27	
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	75°F	72°F	$1,805	$239	$2,952	$4,730	$1,778	7.44	0.13	
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	75°F	70°F	$1,742	$302	$2,952	$4,730	$1,778	5.89	0.17	
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	20.0	10.0	38.0	75°F	68°F	$1,687	$357	$2,952	$4,730	$1,778	4.98	0.20	
	2 x 6 studs, ASHRAE 90.2 Baseline, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	75°F	72°F	$1,788	$256	$2,952	$5,290	$2,338	9.13	0.11	
	2 x 6 studs, ASHRAE 90.2 Baseline, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	75°F	70°F	$1,727	$317	$2,952	$5,290	$2,338	7.38	0.14	
	2 x 6 studs, ASHRAE 90.2 Baseline, R-15 exterior bd. below-grade insulation 8 feet deep	20.0	15.0	38.0	75°F	68°F	$1,674	$370	$2,952	$5,290	$2,338	6.32	0.16	

Table C-13 Improvement Combinations Continued

Envelope	Combinations	Above-Grade R-Value	Basement R-Value	Ceiling R-Value	Cooling Setpoint	Heating Setpoint	Utility Bill	Energy Bill Improvement	Initial Cost	Improvement Cost	Cost Difference	Payback	ROI	Notes
ASHRAE Considerations	2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	75°F	72°F	$1,821	$223	$2,952	$4,749	$1,797	8.06	0.12	R-15 batt plus continuous R-10
	2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	75°F	70°F	$1,748	$296	$2,952	$4,749	$1,797	6.07	0.16	R-15 batt plus continuous R-10
	2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	25.0	5.0	38.0	75°F	68°F	$1,690	$354	$2,952	$4,749	$1,797	5.08	0.20	R-15 batt plus continuous R-10
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	75°F	72°F	$1,780	$264	$2,952	$5,308	$2,356	8.92	0.11	R-15 batt plus continuous R-10
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	75°F	70°F	$1,719	$325	$2,952	$5,308	$2,356	7.25	0.14	R-15 batt plus continuous R-10
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	25.0	10.0	38.0	75°F	68°F	$1,665	$379	$2,952	$5,308	$2,356	6.22	0.16	R-15 batt plus continuous R-10
	2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	30.0	5.0	38.0	75°F	72°F	$1,799	$245	$2,952	$5,610	$2,658	10.85	0.09	R-15 batt plus continuous R-15
	2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	30.0	5.0	38.0	75°F	70°F	$1,734	$310	$2,952	$5,610	$2,658	8.57	0.12	R-15 batt plus continuous R-15
	2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	30.0	5.0	38.0	75°F	68°F	$1,678	$366	$2,952	$5,610	$2,658	7.26	0.14	R-15 batt plus continuous R-15
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	30.0	10.0	38.0	75°F	72°F	$1,766	$278	$2,952	$6,169	$3,217	11.57	0.09	R-15 batt plus continuous R-15
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	30.0	10.0	38.0	75°F	70°F	$1,704	$340	$2,952	$6,169	$3,217	9.46	0.11	R-15 batt plus continuous R-15
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	30.0	10.0	38.0	75°F	68°F	$1,653	$391	$2,952	$6,169	$3,217	8.23	0.12	R-15 batt plus continuous R-15
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	5.0	38.0	75°F	72°F	$1,821	$223	$2,952	$4,170	$1,218	5.46	0.18	R-21 batt plus continuous R-5
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	5.0	38.0	75°F	70°F	$1,755	$289	$2,952	$4,170	$1,218	4.21	0.24	R-21 batt plus continuous R-5
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	5.0	38.0	75°F	68°F	$1,697	$347	$2,952	$4,170	$1,218	3.51	0.28	R-21 batt plus continuous R-5
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	10.0	38.0	75°F	72°F	$1,787	$257	$2,952	$4,729	$1,777	6.91	0.14	R-21 batt plus continuous R-5
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	10.0	38.0	75°F	70°F	$1,726	$318	$2,952	$4,729	$1,777	5.59	0.18	R-21 batt plus continuous R-5
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	26.0	10.0	38.0	75°F	68°F	$1,672	$372	$2,952	$4,729	$1,777	4.78	0.21	R-21 batt plus continuous R-5
	2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	31.0	5.0	38.0	75°F	72°F	$1,801	$243	$2,952	$4,749	$1,797	7.39	0.14	R-21 batt plus continuous R-10
	2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	31.0	5.0	38.0	75°F	70°F	$1,736	$308	$2,952	$4,749	$1,797	5.83	0.17	R-21 batt plus continuous R-10
	2 x 6 studs, ASHRAE 90.2 Baseline, R-5 exterior bd. below-grade insulation 8 feet deep	31.0	5.0	38.0	75°F	68°F	$1,680	$364	$2,952	$4,749	$1,797	4.94	0.20	R-21 batt plus continuous R-10
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	31.0	10.0	38.0	75°F	72°F	$1,767	$277	$2,952	$5,308	$2,356	8.50	0.12	R-21 batt plus continuous R-10
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	31.0	10.0	38.0	75°F	70°F	$1,706	$338	$2,952	$5,308	$2,356	6.97	0.14	R-21 batt plus continuous R-10
	2 x 6 studs, ASHRAE 90.2 Baseline, R-10 exterior bd. below-grade insulation 8 feet deep	31.0	10.0	38.0	75°F	68°F	$1,655	$389	$2,952	$5,308	$2,356	6.06	0.17	R-21 batt plus continuous R-10

Appendix D - Cost Data

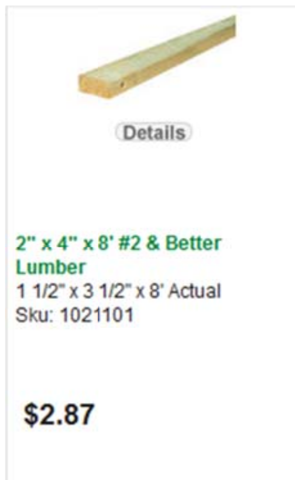
The price of items included in the improvements was used to calculate the payback period for such improvements. The cost of batt insulation, rigid insulation, windows, and HVAC units were found from commercial websites or the RSMeans book. Prices obtained from the manufacturer via telephone were inputted into an Excel spreadsheet for clarity.

Table D-1 Cavity Insulation Costs

Insulation	$/S.F.	Source
R-15 batt	0.42	Home Depot
R-19 batt	0.45	Home Depot
R-21 batt	0.61	Home Depot

Figure D-1 2” x 4” Lumber Costs (menards.com)

8 foot long studs



12 foot long plates

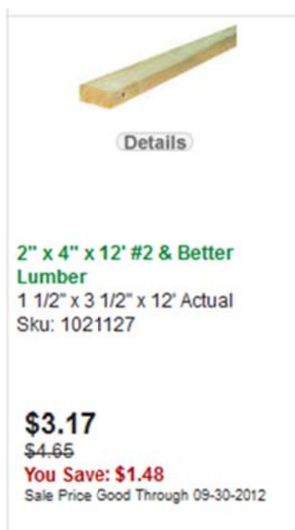
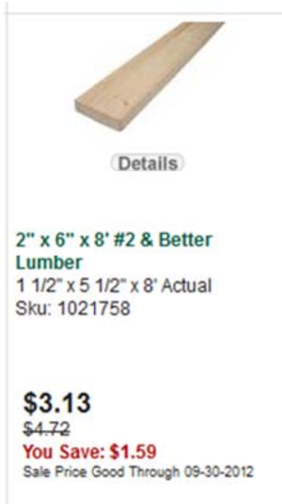


Figure D-2 2” x 6” Lumber Costs (menards.com)

8 foot long studs (mark-up not included)



12 foot long plates

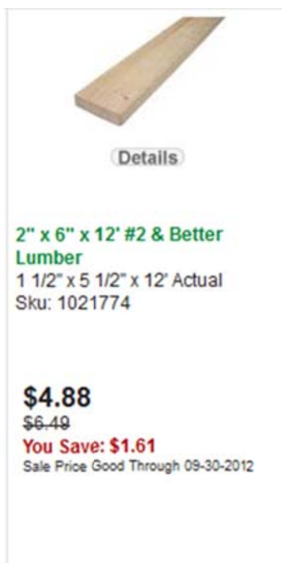


Figure D-3 Above-Grade Rigid Board Insulation Costs

Exterior Board Sheathing

Details

R4 3/4" x 4 x 8 FOAMULAR 250 Rigid Foam Insulation

Tongue & Groove
3/4" x 4' x 8'
Sku: 1631250
Model: 270932

$14.25 each

1” Rigid Board Insulation, R-5

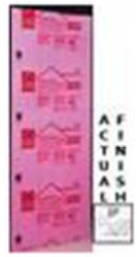
Details

R5 1" x 4 x 8 FOAMULAR 150 Rigid Foam Insulation

Square Edge
1" x 4' x 8'
Model: 270266

Online Price
$14.64 each

1 1/2” Rigid Board Insulation, R-7.5

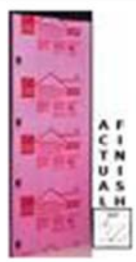


Details

R7.5 1 1/2" x 4 x 8 FOAMULAR 150 Rigid Foam Insulation
Scored Square Edge
1 1/2" x 4' x 8'
Model: 270824

Online Price
$22.44 each

2” Rigid Board Insulation, R-10



Details

R10 2" x 4 x 8 FOAMULAR 150 Rigid Foam Insulation
Tongue & Groove
2" x 4' x 8'
Model: 270919

Online Price
$29.90 each

3” Rigid Board Insulation, R-15

Figure D-4 Below-Grade Perimeter Rigid Board Insulation Costs

1 1/2” CelloFoam Perimeter Insulation Board

Figure D-5 Above-Ceiling Blown Insulation Costs

65 square feet of R-30 loose-fill insulation (originally listed at $31.47)

Table D-2 Above-Ceiling Blown Insulation Costs

Above-Ceiling Blown Insulation	
Insulation	$/S.F.
R-11 Batt Insulation	$0.15
R-13 Batt Insulation	$0.17
R-21 Batt Insulation	$0.30
R-38 Batt Insulation	$0.56
R-49 Batt Insulation	$0.62
R-60 Batt Insulation	$0.70

(SOURCE: RS Means book)

Figure D-6 Jeld-Wen Window Quote

JELD-WEN
WINDOWS & DOORS

QUOTE BY: andy
SOLD TO:

QUOTE #: J100065
SHIP TO:

PO#:

PROJECT NAME:
REFERENCE:

LINE NO.	LOCATION SIZE INFO	BOOK CODE DESCRIPTION	UNIT PRICE	QTY	EXTENDED PRICE
Line- 1	Rough Opening:36 X 60	BLVDH3660 Frame Size: 35 1/2 x 59 1/2 Builders Vinyl Double Hung Window Nail Fin (1 1/4" setback), White Ext/White Int , Vent Height = 30 , Low-E Clear 0 - 3500 feet , Full Box Frame with Fiberglass Mesh, White Int Hardware, Style Cam Lock(s), 2 Locks, *Meets 5.7 sqft Egress (2nd floor and above)*, AAMA, DP-20, PEV 2012.1.1484/PDV 5.655 (03/07/12) IA	$302.04	1	$291 84 ~~$302.04~~
Line- 2	Rough Opening:36 X 60	BLVSL23660 2' x 2' Frame Size: 35 1/2 x 59 1/2 Builders Vinyl Sliding Window Nail Fin (1 1/4" setback), White Ext/White Int , XO (LH) Vent Width = 18 , Low-E Clear 0 - 3500 feet Standard Screen with Fiberglass Mesh, White Int Hardware, Style Cam Lock(s), 2 Locks, *Does Not Meet Egress*, AAMA, DP-20, PEV 2012.1.1484/PDV 5.655 (03/07/12) IA	$257.77	1	$150 90 $231 30 ~~$257.77~~
Line- 3	Rough Opening:36 X 60	VCMT3660 Frame Size: 35 1/2 x 59 1/2 Premium Vinyl Casement Window Nail Fin (1 1/4" setback), White Ext/White Int , Hinge Left, Low-E Clear 0 - 3500 feet Standard Screen with Fiberglass Mesh, White Int Hardware, Scissor Hinge, *Meets 5.7 sqft Egress (2nd floor and above)*, FL# 12426 ,TDI# WIN-461 AAMA, DP-50, PEV 2012.1.1484/PDV 5.655 (03/07/12) IA	$459.31	1	$413 48 ~~$459.31~~


Viewed from Exterior. Scale: 1/4" = 1'


Viewed from Exterior. Scale: 1/4" = 1'


Viewed from Exterior. Scale: 1/4" = 1'

Total: ~~$1,019.12~~
Total Units: 3

QQ-2.10.0.858 cust 055746
Quote Date: 9/14/2012

Page 1 of 1 (Prices are subject to change.)
Drawings are for visual reference only and may not be to exact scale. All orders are subject to review by JELD-WEN

J100065 - 9/14/2012 - 10:53 AM
Last Modified: 9/14/2012

(Quote by: Mead Lumber, Manhattan, KS)

This window was treated as the baseline window installment for each type. The sliding window price was adjusted further because the window size would be 2' x 2' standard instead of 3' x 5'.

Figure D-7 Eagle Window Quote

Triple-Pane Casement Window

Customer Copy

Quote # TBD

Unassigned

MEAD BLDG CENTERS OF MANHATTAN DBA
MEAD LUMBER
111 SO SETH CHILDS

9/21/2012

Eagle WINDOWS & DOORS an Andersen Company

MANHATTAN KS 66502
(785)776-4811 FAX (785)776-5327

Quote TBD
Job Tag
Company

Bid By

Job Site

FAX

Line	Item Number	UM	Qty	Customer Price	Extended Price
100	CCMTS	EA	1	$552.52	$552.52

CLAD CASEMENTS

1 WIDE UNIT, 2 7/8" Wall, Pine, w/Nailfin, No Brickmold, Frame Colony White 2604, Sash Colony White 2604, Colonial Glass Stop,

Axiom 11 Casement, 3-0 X 5-0, LEFT HAND, BRONZE, WHITE ARLOC BULB WEATHERSTIP, FOLDING W/COVER, STAINLESS STEEL, PIANO HINGE, 2 LOCKING POINTS, HI-PERFOMANCE KEEPER, YES, Anneal, H/A, Insulated Glass, Low-E (272), DP POS 30, DP NEG 30, NO SCREEN,

Viewed From Exterior

Rough Opening: 3' 0 1/2" X 5' 0 1/2"

Triple-Pane Double-Hung Window

Quote # TBD

Unassigned

Line	Item Number	UM	Qty	Customer Price	Extended Price
101	CSCREEN	EA	1	$22.59	$22.59

CONFIGURED SCREEN CLAD PRODUCT

Axiom 11 Casement, 3050, BRONZE FIBER MESH SCREEN, NO PREP

Rough Opening: 3' 0" X 5' 0"

Line	Item Number	UM	Qty	Customer Price	Extended Price
200	CDHGS	EA	1	$469.35	$469.35

CLAD DOUBLE HUNGS

1 WIDE UNIT, 4 9/16" Wall, Pine, w/Nailfin, No Brickmold, Frame Colony White 2604, Sash Colony White 2604, BEIGE JAMBLINER, Colonial Glass Stop,

T7 TALON DOUBLE HUNG, 3050, 2 LOCKS, NO LIFTS - NO LIFT PREP, BRONZE, ANNEALED, Insulated Glass, T=Low-E (272), ANNEALED, Insulated Glass, B=Low-E (272), DP POS 30, DP NEG 30, PLASTIC INSERT (INT/EXT), B & T,

Viewed From Exterior

Rough Opening: 3' 0 1/2" X 5' 0 1/2"

Triple-Pane Sliding Window

Quote # TBD Unassigned

Line	Item Number	UM	Qty	Customer Price	Extended Price
201	CSCREEN	EA	1	$26.11	$26.11

CONFIGURED SCREEN CLAD PRODUCT

T7 TALON DOUBLE HUNG, 3050, FULL SCREEN, WHITE FIBER MESH

Rough Opening: 3' 0" X 5' 0"

Line	Item Number	UM	Qty	Customer Price	Extended Price
300	CSLDS2	EA	1	$495.85	~~$495.85~~ $300.00

CLAD SLIDE-BY WINDOWS

1 WIDE UNIT, 4 9/16" Wall, Pine,w/Nailfin, No Brickmold, Frane Colony White 2604, Sash Colony White 2604, Colonial Glass Stop,

SLIDER, CSLD-02, ~~3~~ 2, 0, 0, ~~5~~ 3, 0, 0, XO, EQUAL, BEIGE, 2 LOCKS, ONE PULL, BRONZE, Anneal, Anneal, L=Low-E (272), R=Low-E (272), DP POS 30, DP NEG 30, PREP FOR 1/2 SCREEN,

Rough Opening: 3' 0 1/2" X 5' 0 1/2"

(Quote by: Mead Lumber, Manhattan, KS)

These windows were used as the triple-pane window provided in the ACCA Load Calculation manual. Again, the sliding window price was adjusted because it would be a 2’ x 2’ window (roughly) instead of the quoted 3’ x 5’ window.

Table D-3 Pella Window Quotes

	Casement	Double-Hung	Sliding
Window Type	3' x 5'	3' x 5'	2' x 2'
Pella Advanced Low-e IG with Argon	$434	$494	$85
Pella SunDefense Low-e IG with Argon	$456	$517	$85
Pella SunDefense Dual Low-e IG with Argon	$477	$539	$85
Pella Tinted; Bronze Advanced Low-e IG w/ Argon	$456	$517	$85
Pella Gray Advanced Low-e IG w/Argon	$456	$517	$85

(Quote by: Pella Windows of Kansas, Manhattan, KS)

Appendix E - Glass Performance Data

The window U-values were determined from the manufacturer. Pella had the U-values available on their website and they were inputted into the model depending on the window type. Casement, Double-Hung, and Sliding type windows were the types chosen for this analysis because they are the window types currently installed in the residence. The U-value and VLT% were the numbers pulled from Pella's website while the SHGC remained unchanged and was kept at what was calculated for the heating and cooling loads. The letters located next to the description coordinates with the improvement option listed on the glass improvement spreadsheet. Only one option is shown for the basement sliding windows because the U-values remained fairly constant amongst the different window types.

Figure E-1 Double-Hung Window U-Values

Architect Series® | Designer Series® | Pella® ProLine

DOUBLE-HUNG

GLAZING PERFORMANCE - TOTAL UNIT

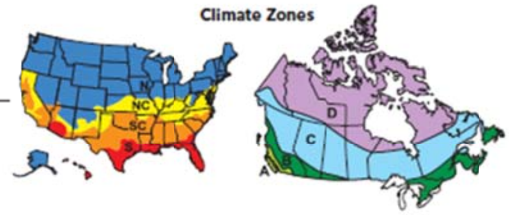
Architect Series® Clad

Type of Glazing	U-Factor[1]	SHGC	VLT %	CR	Shaded Areas Meet ENERGY STAR® Performance Criteria in Zones Shown: U.S. Zone N	NC	SC	S	Canada[2] ER	Canada[2] Zone A	B	C	D
11/16" clear IG with 2.5 mm glass	0.47	0.60	63	43									
with grilles-between-the-glass	0.47	0.54	56	43									
with integral grilles	0.47	0.54	56	43									
11/16" Advanced Low-E IG with argon with 2.5mm glass E	0.30	0.28	54	58					17				
with grilles-between-the-glass	0.30	0.26	48	58					16				
with integral grilles	0.30	0.26	48	58					16				
11/16" NaturalSun Low-E IG with argon with 2.5mm glass	0.32	0.54	60	56					29				
with grilles-between-the-glass	0.32	0.49	54	56					27				
with integral grilles	0.32	0.49	54	56					27				
11/16" SunDefense™ Low-E IG with argon with 2.5 mm glass F	0.29	0.21	50	58					14				
with grilles-between-the-glass	0.29	0.19	44	58					13				
with integral grilles	0.30	0.19	44	58					12				
11/16" SunDefense Dual Low-E IG with argon with 2.5 mm glass G	0.26	0.20	46	48					17				
with grilles-between-the-glass	0.26	0.18	41	48					16				
with integral grilles	0.26	0.18	41	48					16				
TINTED GLAZING H													
11/16" Bronze Advanced Low-E IG w/argon with 5 mm/3 mm Low-E	0.30	0.25	34	56					15				
with grilles-between-the-glass	0.32	0.23	31	56									
with integral grilles I	0.32	0.23	31	56									
11/16" Gray Advanced Low-E IG w/argon with 5 mm/3 mm Low-E	0.30	0.23	30	56					14				
with grilles-between-the-glass	0.32	0.21	26	56									
with integral grilles	0.32	0.21	26	56									
11/16" Green Advanced Low-E IG w/argon with 5 mm/3 mm Low-E	0.30	0.24	42	56					15				
with grilles-between-the-glass	0.32	0.22	37	56									
with integral grilles	0.32	0.22	37	56									
HIGH ALTITUDE GLAZING													
11/16" Advanced Low-E HA IG with 2.5mm glass	0.33	0.29	54	54									
with grilles-between-the-glass	0.33	0.26	48	54									
with integral grilles	0.34	0.26	48	54									
11/16" NaturalSun Low-E HA IG with 2.5mm glass	0.35	0.54	60	53					26				
with grilles-between-the-glass	0.35	0.48	54	53					22				
with integral grilles	0.36	0.48	54	53					21				
11/16" SunDefense Low-E HA IG with 2.5 mm glass	0.33	0.21	50	55									
with grilles-between-the-glass	0.33	0.19	44	55									
with integral grilles	0.33	0.19	44	55									
11/16" SunDefense Dual Low-E HA IG with 2.5 mm glass	0.28	0.20	46	44					15				
with grilles-between-the-glass	0.28	0.18	41	44					14				
with integral grilles	0.29	0.18	41	44									

R-Value = 1/U-Factor
SHGC = Solar Heat Gain Coefficient
VLT % = Visible Light Transmission
CR = Condensation Resistance
ER = Canadian Energy Rating

See the Product Performance section for more detailed information or visit www.energystar.gov for Energy Star guidelines.

Climate Zones



(1) Glazing performance values are calculated based on NFRC 100.
(2) The values shown are based on Canada's updated ENERGY STAR® initiative.
For center-glass values, see the Product Performance section.
See Casement Section for Fixed unit Glazing Performance.

Figure E-2 Casement Window U-Values

Architect Series® | Designer Series® | Pella® ProLine

CASEMENT

GLAZING PERFORMANCE - TOTAL UNIT

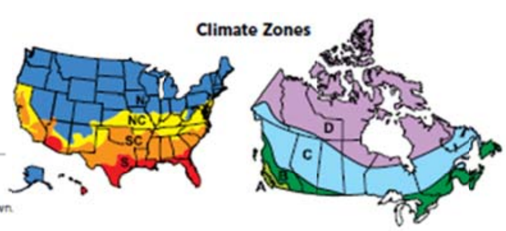
Architect Series® Aluminum-Clad Wood - Vent

Shaded Areas Meet ENERGY STAR® Performance Criteria in Zones Shown

Type of Glazing	U-Factor[1]	SHGC	VLT %	CR	U.S. Zone N	NC	SC	S	Canada[2] ER	Zone A	B	C	D
VENT													
11/16" clear IG with 3 mm glass	0.45	0.54	56	43					15				
with grilles-between-the-glass	0.45	0.49	51	43					12				
with integral grilles	0.45	0.49	51	43					12				
E 11/16" Advanced Low-E IG with argon with 3 mm glass	0.29	0.26	48	58					19				
with grilles-between-the-glass	0.29	0.24	43	58					18				
with integral grilles	0.30	0.24	43	58					16				
11/16" NaturalSun Low-E IG with argon with 3 mm glass	0.30	0.48	54	57					30				
with grilles-between-the-glass	0.30	0.43	49	57					27				
with integral grilles	0.31	0.43	49	57					26				
F 11/16" SunDefense™ Low-E IG with argon with 3 mm glass	0.29	0.19	44	58					15				
with grilles-between-the-glass	0.29	0.18	40	58					14				
with integral grilles	0.29	0.18	40	58					14				
G 11/16" SunDefense Dual Low-E IG with argon with 3 mm glass	0.26	0.19	41	46					18				
with grilles-between-the-glass	0.26	0.17	37	46					17				
with integral grilles	0.26	0.17	37	46					17				
TINTED GLAZING													
H 11/16" Bronze Advanced Low-E IG w/argon with 5 mm/3 mm Low-E	0.30	0.23	31	57					16				
with grilles-between-the-glass	0.31	0.21	28	57					13				
with integral grilles	0.31	0.21	28	57					13				
I 11/16" Gray Advanced Low-E IG w/argon with 5 mm/3 mm Low-E	0.30	0.21	27	57					15				
with grilles-between-the-glass	0.31	0.19	24	57					12				
with integral grilles	0.31	0.19	24	57					12				
11/16" Green Advanced Low-E IG w/argon with 5 mm/3 mm Low-E	0.30	0.23	38	57					16				
with grilles-between-the-glass	0.31	0.21	34	57					13				
with integral grilles	0.31	0.21	34	57					13				
HIGH ALTITUDE GLAZING													
11/16" Advanced Low-E HA IG with 3 mm glass	0.32	0.26	48	54					15				
with grilles-between-the-glass	0.32	0.24	43	54					14				
with integral grilles	0.33	0.24	43	54					13				
11/16" NaturalSun Low-E HA IG with 3 mm glass	0.33	0.47	54	54					26				
with grilles-between-the-glass	0.33	0.43	49	54					24				
with integral grilles	0.34	0.43	49	54					22				
11/16" SunDefense Low-E HA IG with 3 mm glass	0.32	0.20	44	55					12				
with grilles-between-the-glass	0.32	0.18	40	55					10				
with integral grilles	0.33	0.18	40	55					9				
11/16" SunDefense Dual Low-E HA IG with 3 mm glass	0.28	0.19	41	43					16				
with grilles-between-the-glass	0.28	0.17	37	43					15				
with integral grilles	0.29	0.17	37	43					14				

R-Value = 1/U-Factor
SHGC = Solar Heat Gain Coefficient
VLT % = Visible Light Transmission
CR = Condensation Resistance
ER = Canadian Energy Rating

See the Product Performance section for more detailed information or visit www.energystar.gov for Energy Star guidelines.



(1) Glazing performance values are calculated based on NFRC 100.
(2) The values shown are based on Canada's updated ENERGY STAR® initiative.

Based on unit size, some products will use 2.5mm glass that may have improved glazing performance from what is shown.

Figure E-3 Sliding Window U-Values

10 Series | 20 Series | 25 Series

SLIDING WINDOW

GLAZING PERFORMANCE – TOTAL UNIT

Sound Transmission Class

East Region Only

Type of Glazing	U-Factor[1]	SHGC	VLT %	CR	N	NC	SC	S
	10/20 Series				Meets U.S. ENERGY STAR® Performance Criteria in Region Shown[2]			
3/4" CLEAR IG OR OBSCURE / CLEAR IG								
No Grille	0.48	0.63	66	42				
with 3/4" Contour Grille	0.48	0.56	59	42				
with 1" Contour Grille	0.49	0.50	52	42				
3/4" ADVANCED LOW-E IG OR OBSCURE ADVANCED LOW-E IG								
No Grille	0.34	0.30	56	54				
with 3/4" Contour Grille	0.34	0.27	50	54				
with 1" Contour Grille	0.35	0.24	44	54				
3/4" SUNDEFENSE™ LOW-E IG OR OBSCURE SUNDEFENSE™ LOW-E IG								
No Grille	0.33	0.23	52	54				
with 3/4" Contour Grille	0.33	0.21	46	54				
with 1" Contour Grille	0.35	0.19	41	54				
3/4" ADVANCED LOW-E IG WITH ARGON OR OBSCURE ADVANCED LOW-E IG WITH ARGON								
No Grille Basement	0.30	0.30	56	58				
with 3/4" Contour Grille	0.30	0.27	50	58				
with 1" Contour Grille	0.31	0.24	44	58				
3/4" SUNDEFENSE™ LOW-E IG WITH ARGON OR OBSCURE SUNDEFENSE™ LOW-E IG WITH ARGON								
No Grille	0.30	0.22	52	57				
with 3/4" Contour Grille	0.30	0.20	46	57				
with 1" Contour Grille	0.31	0.18	41	57				
3/4" BRONZE ADVANCED LOW-E IG WITH ARGON								
No Grille	0.30	0.30	43	58				
with 3/4" Contour Grille	0.30	0.27	38	58				
with 1" Contour Grille	0.31	0.24	34	58				

Climate Zones

Sound Transmission Class and Outdoor-Indoor Transmission Class

Series	Product	Frame Size	Glazing System	STC Rating	OITC Rating
10	Sliding Window	72" x 48"	3/4" clear IG with 2.5 mm glass	26	21

KEY:

R-Value = 1/U-Factor
SHGC = Solar Heat Gain Coefficient
VLT % = Visible Light Transmission
CR = Condensation Resistance

East Region Only

(1) Glazing performance values are calculated based on NFRC 100.
(2) Climate Zones: N = Northern, NC = North/Central, SC = South/Central, S = Southern. For more information, see the Energy Star guidelines.
See the Product Performance section for center-glass values and other detailed information.
Based on unit size, some products will use 2.5mm glass that may have improved glazing performance from what is shown.