Energy

Neighborhood Energy Profile Database & Energy Efficiency Recommendations

CONNECT *Our Future*

Vibrant Communities–Robust Region

The 14-county bi-state region includes: Anson, Cabarrus, Cleveland, Gaston, Iredell, Lincoln, Mecklenburg, Rowan, Stanly and Union Counties in North Carolina, and Chester, Lancaster, Union and York Counties in South Carolina.

Neighborhood Energy Profile Database & Energy Efficiency Recommendations

- Developing a way to assess home energy performance that's understandable by all homeowners
- Helping to reduce home energy costs by interventions at all phases of residential planning and development
- Putting more money back in residents' pockets and creating job opportunities in the energy sector

"CONNECT Our Future" is a process in which communities, counties, businesses, educators, non-profits and other organizations work together to grow jobs and the economy, improve quality of life and control the cost of government. This project will create a regional growth framework developed through extensive community engagement and built on what communities identify as existing conditions, future plans and needs, and potential strategies.

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This document was prepared by Centralina Council of Governments and Catawba Regional Council of Governments in partnership with GREENTHINC., PLLC

GREENTHINC. PLLC
Working towards carbon-neutral building environments

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Executive Summary

Residential building energy consumption, specifically the owner-occupied single-family detached home, has not received the same level of attention regarding energy consumption as that of the commercial building sector. This study aims to identify energy consumption characteristics of this home type in our Piedmont Region through observing the home lot characteristics, measuring the physical building performance, assessing the homeowner utility history and monitoring the energy consumption of the home. This study also aims to identify where energy consumption problems may exist, propose an assessment of and provide solutions for bettering the performance of the homes.

Figure 1. CONNECT Participating Counties

It is important to note that all homeowners should find this study as a useful and informative tool to assist them in the daily operations of their home and needs for a comfortable living environment. Although no two homes are exactly the same, this study aims to identify common energy problems and propose no cost-to-low cost solutions that will lead towards better comfort and affordability.

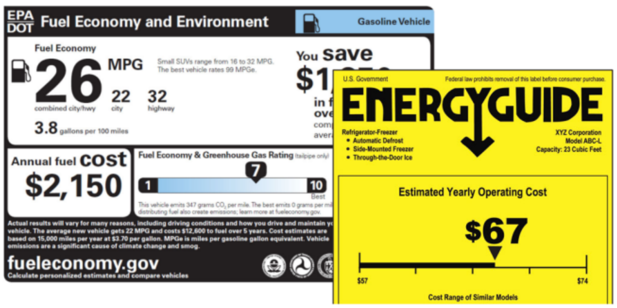
When considering how this information will apply to the larger context of our region it is important to acknowledge that if one single family home can be enhanced for better performance then it is true that many more homes may benefit as well. A conservative 20:1, or more optimistic 10:1 ratio of performance enhancements says that if twenty homes receive upgrades that lead towards a five percent decrease in utility resource use for each home, or if ten homes are able to reduce their utility resource use by ten percent each then the full utility resources will be available for one new additional home at no draw down in utility resource capacity. Ideally, the cost of reduced utility resources at each home will decrease proportionally with the enhancements but no guarantee can be made that the utility unit costs will not increase.

Figure 2. A sample of participating homes

So, for every 1,000 existing homes that receive performance upgrades the potential exists for 50 to 100 additional new homes to be operated at no additional utility resource production. This does not account for the resource usage in the harvesting and extracting of materials, manufacturing, transportation and construction of the home. It only speaks to the utility resources of energy required to operate the home.

Energy Labels

One of the goals of this study is to highlight the need for clear communication on the performance of homes to current or potential homeowners in the Piedmont region. Similar to the MPG labeling for automobiles or the Energy Guide for appliances a snapshot metric is needed for a home buyer decision making. The HERS (Home Energy Rating System) Index is the industry standard metric that is being adopted throughout the country and implemented through the Multiple Listing Service (MLS) during property transactions. A HERS index of 70 indicates that a home is 30% more efficient than the standard new home. An index of 130 indicates that a home is 30% less efficient than the standard new home. This metric label is one opportunity for homeowners to increase their decision making process when looking to purchase a new or existing home.



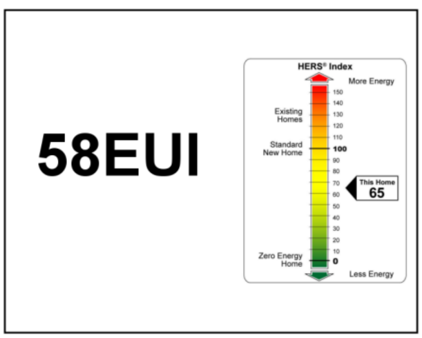


Figure 3. Energy Use Labels; EPA MPG, FTC EnergyGuide, Energy Use Index (EUI) and HERS Index

As a planning study only, this project made no corrective actions to any found problems during the project period. However, the residential building industry has continued to develop awareness of energy-related problems and provide corrective field actions to help resolve the issues. The strong growth of Weatherization companies across the country and in our Piedmont Region is clear evidence of this awareness. This study will highlight the common corrective actions and available local resources for the homeowners to call on.

Project Marketing

The U.S. Green Building Council – North Carolina Chapter (USGBC NC) supported NEPDEER's marketing and outreach. The USGBC NC provided staff time and talent to create a brochure and flier that explain the program. USGBC NC also helped distribute information about the program to a diverse audience throughout the NC counties included in CONNECT. Promotion of NEPDEER was included on the USGBC NC website, press releases and in the weekly email distribution to several thousand addresses.

Project Team

This project was managed by the architectural firm, GREENTHINC, PLLC. The marketing and homeowner solicitation for the project was provided by US Green Building Council - North Carolina Chapter (USGBC-NC). The data management was provided by the architectural firm, Cort Architectural Group, PA. The home site and building audit and diagnostic testing was provided by GREENTHINC and Efficiency First, LLC, respectively. The historic duct sealing data was provided by Fresh Air Technologies, Inc. The on-site home energy monitoring was provided by Lucid Solutions, LLC.

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CORT ARCHITECTURAL GROUP, PA

U.S. GREEN BUILDING COUNCIL NORTH CAROLINA CHAPTER

elm energy group

LUCID MEASURE INTEGRATE INNOVATE

Fresh Air Technologies, LLC.

Assessment and Process

At the heart of this study were the participating homeowner applicants and their corresponding home energy characteristics determined through survey questionnaires, on-site home energy audits and on-site home energy monitoring. Supplemental residential energy information from multiple local resources was made available to the project team, as well as publicly available national data from the Department of Energy and Energy Information Administration. Our process to glean useful and communicable information took place over the past eighteen months between consultants of various expertises.

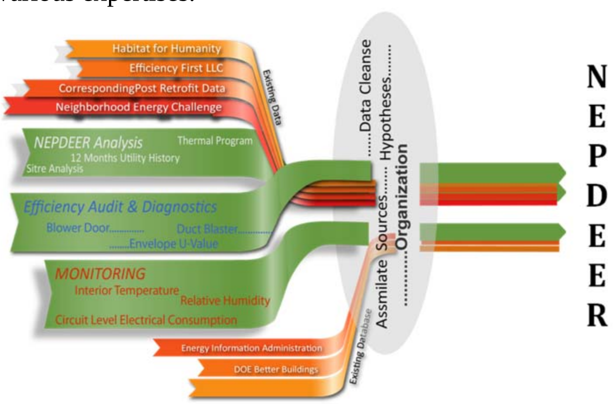

Figure 4. Process Flow Chart

The on-site energy audits resulted in reports that demonstrated areas of concern in graphical formats for air leakage as well as site-to-program thermal imbalances. The home owner utility history assessment provided graphical documentation through charts and graphs of where the home energy was actually consumed. The on-site home energy monitoring provided real-time monitoring with graphical dashboard display that home owners could monitor directly. Our goal has always been to be able to communicate the information in common terms for accessibility by all homeowners, not just building related professionals.

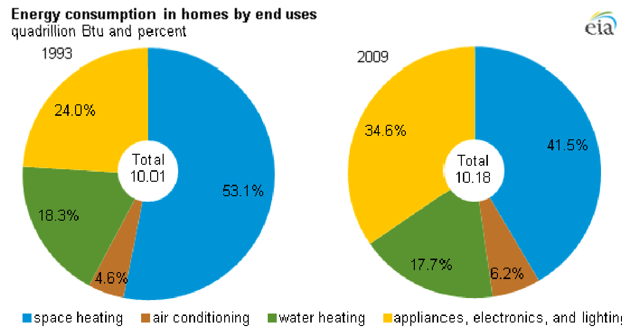

Figure 5. Where does residential energy go? Provided by EIA

Key Findings Overview

The "Arch of Findings" describes, in an analogous way, the importance of the homeowner for the continued long-term support of energy improvements in the home or neighborhood - they are indeed the keystone that holds their energy system in place. Their "Quality of Life" is supported by the proper understanding, use and maintenance of the various parts of the home that affect their comfort and resource consumption. Education and knowledge about fundamental energy use, air infiltration, lighting, water heating, landscaping and thermal conditions is the most important factor that will lead to better energy management, comfort and cost reductions for the homeowner.

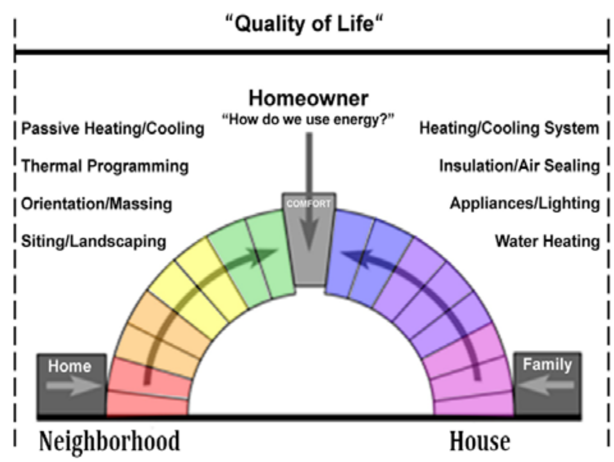

Figure 6. "Arch of Findings" | List of Improvement Areas

The left side of the arch lists "passive" elements that are more easily affected by a new construction or renovation with exception to landscaping and planting activities.

Passive elements are mostly fixed-in-place with no moving parts and require no energy to function. This is very important when planning a new neighborhood or even a single new home. The right side of the arch lists mostly "active" elements of existing houses which can be enhanced and upgraded over time. Active elements are mostly the mechanical elements in the home that require energy and maintenance to function. This is important for homeowners looking for immediate ways to reduce their monthly utility bills and increase their personal comfort.

Of the elements listed there are two items that have the highest potential to reduce utility costs and increase comfort. Where a problem exists of too much direct summertime sun into a warm part of the home, such as the kitchen, planting a deciduous tree on that westerly portion of the lot can reduce the amount of direct sun entering the home thereby helping to cool the space.

Figure 7. HVAC duct leakage reduces comfort and increases utility cost

The other item that is found throughout most, if not all, homes is air infiltration and losses through poorly sealed roof, ceiling, wall and floor penetrations, and HVAC ductwork. These areas of leakage are very small and difficult to see. Poorly sealed wall penetrations such as electrical power outlets and switches on the exterior walls can be more easily detected in the winter time by removing the cover plate and holding your hand next to them.

Air leakage can be mitigated through easy to use measures such as caulk, foam insulation, tape and mastic. Detection and accessibility to all areas of infiltration and leaks can be difficult for the Do-It-Yourself type homeowners so a call to a local Home Weatherization company is recommended.

Section 1 - Project Measures

This project employed a team of experts in the building industry that included a non-profit messaging partner for outreach to homeowners, architects, an energy auditing company and a home energy monitoring company. Each served a specific role that was integral to the development and progress of the study. After our fourteen county/bi-state outreach period for homeowner participation concluded we forwarded Homeowner Application Forms (HAF) to all interested homeowners and received completed forms back from over one hundred interested families. As the first step of vetting participants in the upcoming energy audit phase, we used the HAF's to qualify participation by diversity of location as well as diversity of home and family demographics. Our chief goal was to include homeowners from all fourteen participating counties, provide a mix of house type characteristics and family sizes. We selected homeowners ranging from one disabled senior in 900sf to a family of eight children in 3,400sf.

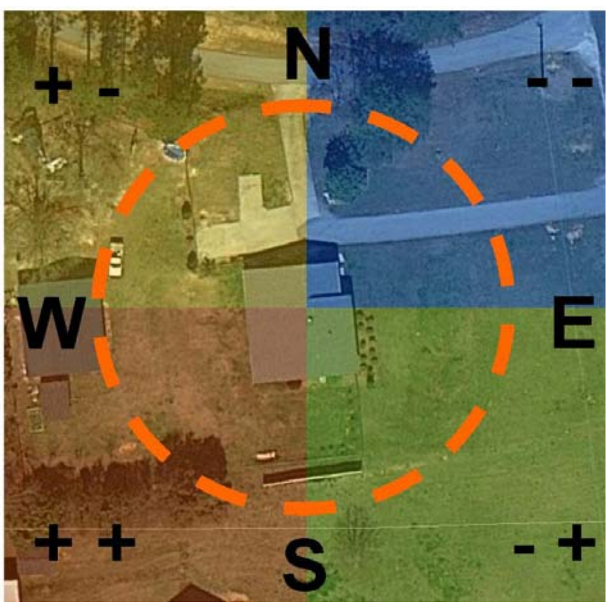

Figure 8. Site-to-Home orientation and massing

Site & Home Audit

The energy audit phase took visual and diagnostic measures of the homes location, lot orientation, building massing, space arrangement, age and type of equipment, air infiltration of the building envelope, insulation thickness and duct leakiness.

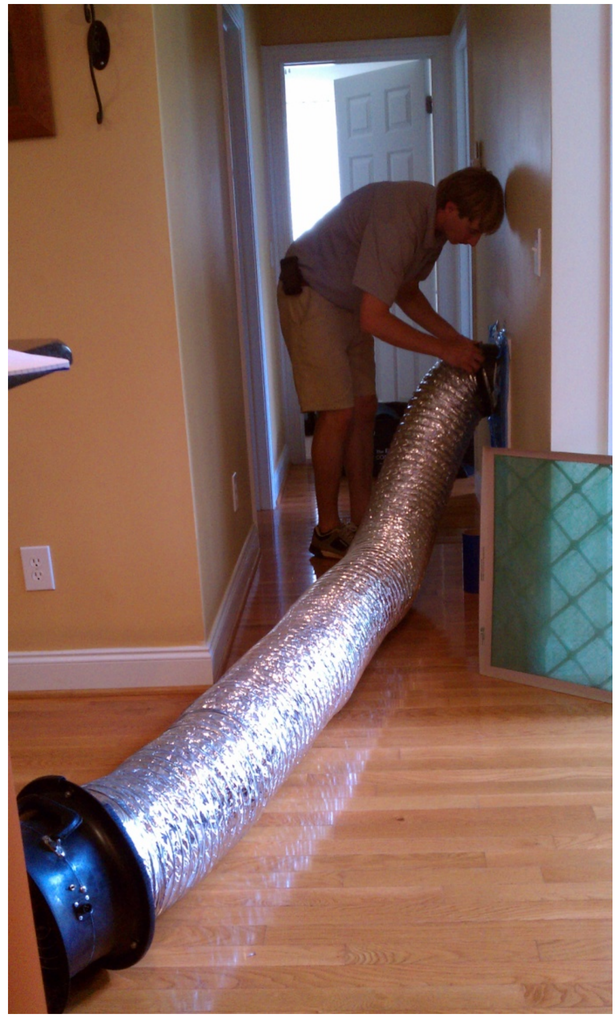

Figure 9. Duct Blaster diagnostics test underway

As the energy audit phase was underway we used the audit findings to select homeowners for the upcoming energy monitoring phase. Again, we chose homeowners across the region for the monitoring phase and targeted homes where the energy monitoring would help homeowners learn about the actual use of energy in their home and how their systems actually perform.

While the purpose of the project was to create the case for energy efficiency, we also needed to provide a deliverable to the customer for their time and involvement. Our goal was to provide a custom tailored report and improvement plan to the customer the same day that the audit took place. We looked at over 50 different data sets in a home ranging from area of wall construction type to insulation R-value and provided two very important tests that gave us feedback on integral parts of the home which made the case for improvement. The Blower Door Test provides a measured calculation of air leakage in the building roof, wall and floor construction based on a preset air pressure baseline. Similarly, the Duct Blaster test provides a measured calculation of air leakage in the heating and cooling ductwork system based on a preset air pressure baseline. These two tests showed that the majority of audited homes, especially homes greater than 20 years old, had higher instances of air loss due to construction methods, age and wear.

Overall, we found a great mix of performance in homes. Typical improvement measures varied from 5-15 years for payback. However, given the time we spent in person with the customer explaining the audit reports, we were able to inform them on the additional values and benefits (comfort, air quality, durability) of some of the longer payback period items. The more engaged a customer was, the more they were already making energy conscious decisions. Homeowners experiencing home performance problems such as moisture control, decreased comfort and poor air quality were less driven by the financial aspect of making improvements and more by the testing and inspection potential to lead to resolving their issues. Homes that were built within the last 10-15 years had a more difficult time utilizing a package of services that had high impact with longer payback timeframes. We recognize that this is due to enhanced energy code standards impacting building construction in areas such as moisture and vapor barrier requirements, increased insulation R-value levels, increased thermal performance of windows, and HVAC systems efficiency increases.

Utility History Assessment

Utility history was gathered from NEPDEER audit applications. One year's worth of monthly gas, electricity, and water use history was set as a prerequisite for audit application. Applications were accepted over a six month period and the data ranges from May 2012-13 to November 2012-13.

Energy Conversion

Since the units used to measure gas and electric use differ widely, and pricing for energy changes from year to year, "therms" and "kWh" are typically converted into a common unit in order to gain a comparative understandings of total energy use.

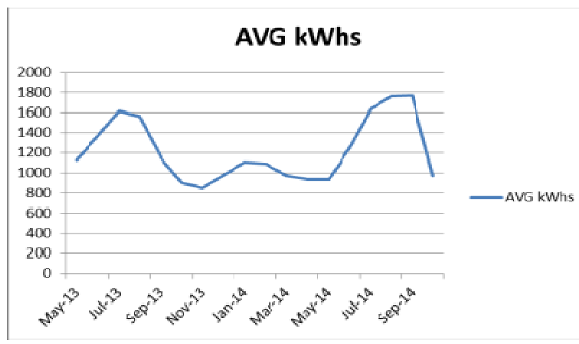

Figure 10: Electric Energy use in kWhs

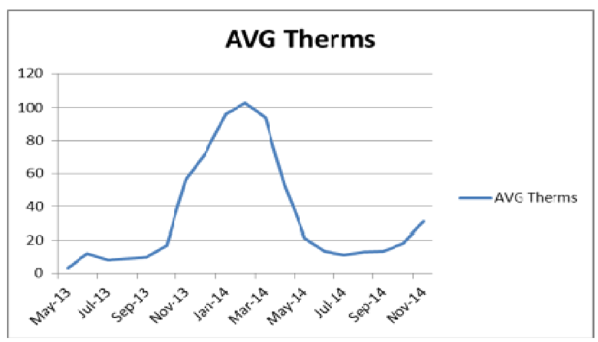

Figure 11: Gas Energy use in therms

Monthly gas and electric use was converted to British Thermal Units or "btu's". It will be commonly referred to in this report in thousands or "kbtus".

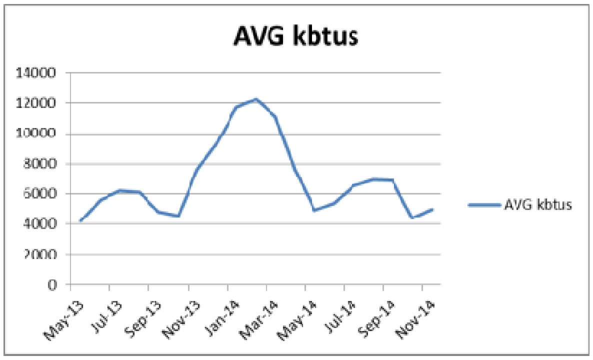

Figure 12: Total Energy use in kbtus

Energy Use Comparisons - EIA

Once a total monthly/yearly picture of energy use is created, comparison to regional averages can be made using information available from the Energy Information Agency (EIA) Energy use is reported by EIA in many formats including *see Appendix* for applicable information:

- Energy use per square foot
- Energy use by housing type
- Energy use per home occupant

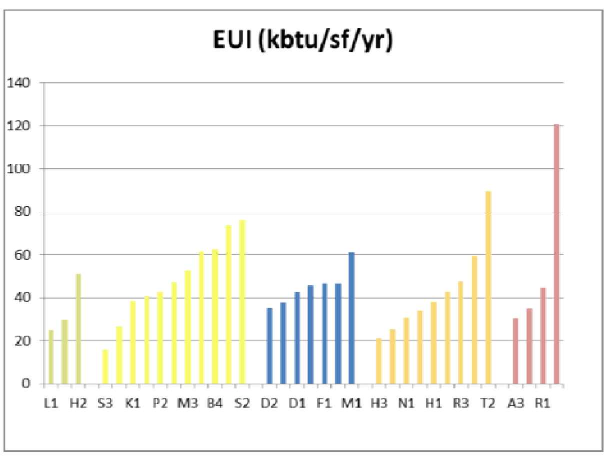

Figure 13: EUI, Energy use vs. regional averages, Energy use segregated into occupant groupings

Base Load vs. Heating/Cooling Load

Each home was assigned an estimated base load energy use amount. The base load is the typical amount of energy consumed by the home and equipment that is not affected by air temperature or weather fluctuations: not heating, ventilating, or air conditioning (non-HVAC). This estimated amount was taken from the month in which energy use was at the lowest. This month of least energy use usually occurs in the fall or spring and is lowest because temperatures are most moderate during these months and HVAC systems are using their least amount of energy. The month of least use is the base load estimate and is used as the base for each month for that year.

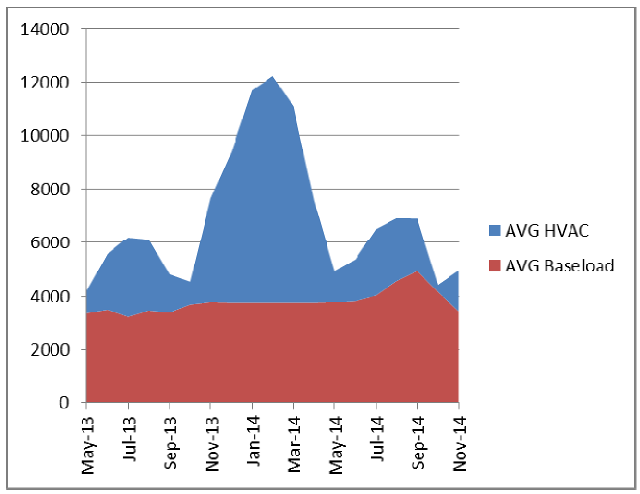

Figure 14: Average HVAC vs. Base Load energy use

Base Load

The accuracy of base load estimating using this method is limited due to:

- Variability of base loads during the year
- HVAC load during the month of least use is not known

Typical base loads include:

- Water heating
- Plug loads/electronics
- Cooking gas

- Major appliances
- Lighting

Figure 15: Yardstick Score Label

Heating/Cooling Load

Heating and cooling loads vary based upon yearly weather trends. In order to account for these localized conditions the Energy Star section of the Federal Environmental Protection Agency (EPA) has developed a weather normalized calculation that compares energy used each month to the total reported "Degree Days" in the local area. This "product" is called Energy Star – Yardstick, and is either available as a web based widget (for individual homes) or computation based spreadsheet (for multiple homes).

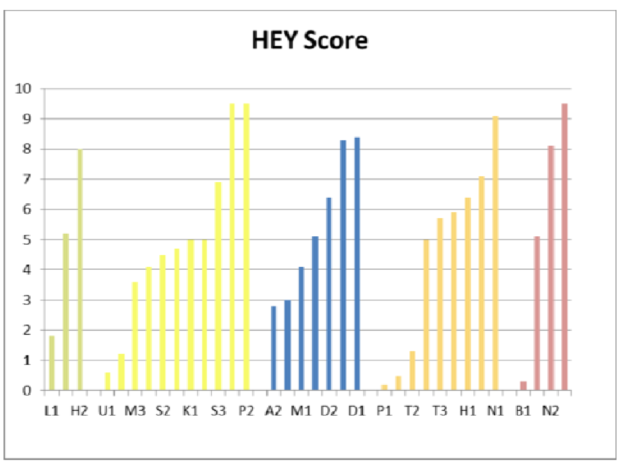

Figure 16: Yardstick score of NEPDEER Homes

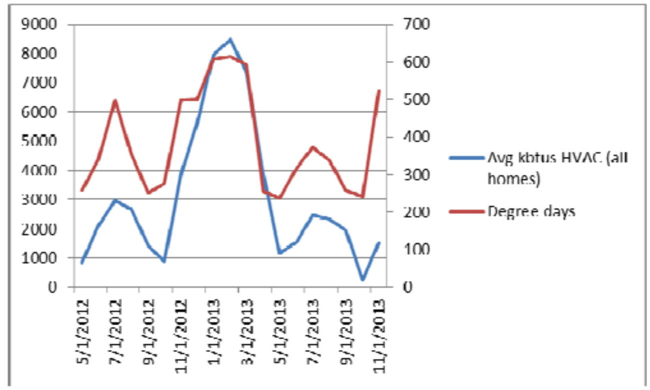

Figure 17: Average HVAC energy consumption vs. Degree Days

Energy Monitoring

Our project also deployed on-site energy monitoring equipment in participating homes as a real-time monitor of the actual daily energy usage. The primary goal for the monitoring was to gain a closer look into the separate energy using devices within the home, record the actual daily usage, and compare this to the utility history information provided by the homeowners. The monitoring equipment was connected to different circuits in the home electrical panel such as a HVAC dedicated circuit, water heater or kitchen zone circuit. This real-time information gave the homeowner immediate feedback on their energy usage via a provided web-based energy dashboard and provided the project team with valuable information to continue the energy use assessment.

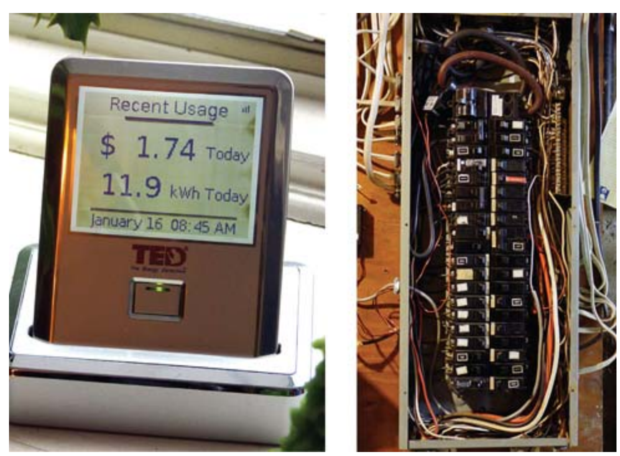

Figure 18. Energy monitoring dashboard and typical panel

The main goal for monitoring the actual energy use in the home was to compare the data to their utility bill history, show individual energy using components of their home and how their daily energy use actually occurs. This information is currently not widely, or freely, available at this scale and it is up to the individual homeowner to achieve this information on their own. Our project provided the equipment and monitoring at no charge to the participating homeowners.

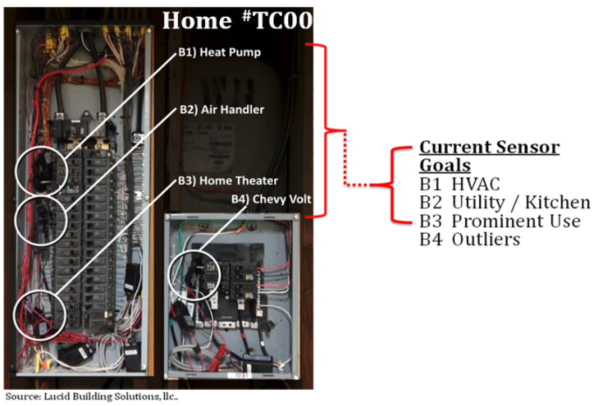

Figure 19. Energy monitoring sensors in typical panel

An example of the type of output that we are using from the monitored energy usage is represented in the following line graph of HVAC daily energy usage over a four month period in a home located In Mecklenburg county *(figure 20)*. The key item to note is the drop in HVAC usage as the more moderate season approaches. As the cooler temperatures arrive the HVAC system is used much less for both cooling and heating. The days in which the HVAC system was used less, likely due to vacations and more comfortable outside temperature, are represented by the troughs in the line graph. This graph also demonstrates the variability of the weather pattern and corresponding temperature here in the Piedmont region as shown by the steep increases and declines in energy usage over short periods of time.

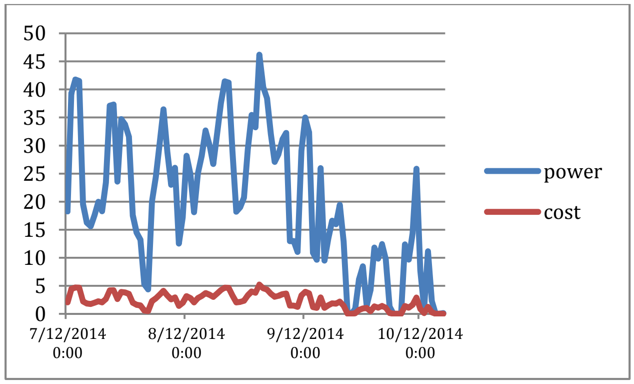

Figure 20. Daily summer and fall monitored HVAC usage in one Mecklenburg County home

Section 2 – Audit & Assessment Activities

Site-to-Home Thermal Relationship

The detached, single-family dwelling is heavily affected by the external temperature, humidity, wind, sun exposure and shade. Unlike commercial buildings that accommodate a lot of heat-generating equipment and people throughout the day, the typical house indoor temperature generally reflects that of the local outdoor temperature. On average, the time of day when the home is mostly occupied is in the evenings and on weekends due to school, errands and workplace hours.

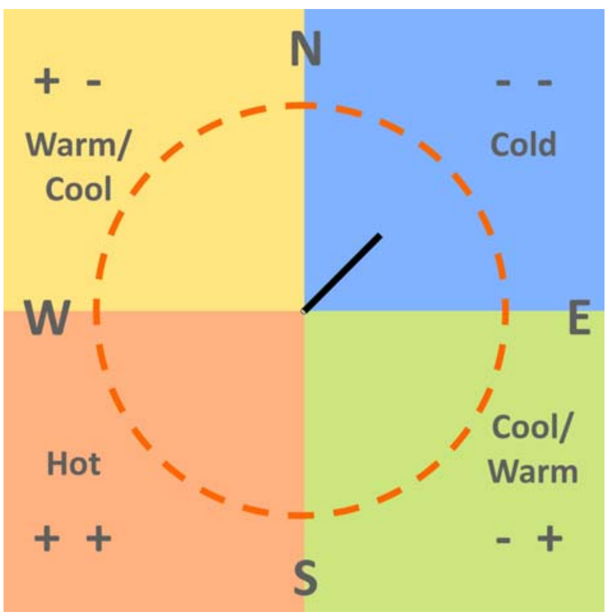

Figure 21. Site thermal quadrants

For the vast majority of homes in the southeast Piedmont region, more electricity and gas is used for heating our homes rather than for cooling them. While not common knowledge, it makes sense when you look at the time of day and season when families are home together. The summer time indoor use of homes is less that of winter time due to warmer weather allowing for outdoor activities, vacations, summer camps and general outdoor enjoyment. Conversely, the indoor use of homes length of time increases as the winter season approaches and daylight hours shorten.

The "Site Thermal Quadrants" graphic represents the general layout of a residential lot and the sun exposure variation along with corresponding ambient outdoor temperature throughout the day. The graphic is simplified to express the point that the southwest corner of a lot will generally be the hottest part of the site due to the increased outdoor temperature throughout the day and the direct setting sun exposure. Conversely, the northeast corner of a lot is generally the coolest part of a site as the ambient temperature of the day is still cool from nighttime darkness and the lack of direct sun exposure. These rule of thumbs become apparent once a home is constructed on the site.

Figure 22. Typical home program spaces

Similar to the temperature variations of the site, a home's interior temperature can vary due to the type of spaces and time of use. For example, consider the hottest part of the house, the Kitchen, and the coolest part of a house, the Bedroom. The kitchen equipment usage is the primary reason for increased heat levels in a home as well as kitchens tend to be where families gather during the day's end and evening dinner. The opposite is true for the bedroom as it is used very little during the daytime and primarily occupied at night time which is the coolest part of any day, winter or summer.

One of the measures to passively heat and cool a home takes place during the initial planning stages of a new home or major renovation where spaces may be rearranged. If we look at just the thermal characteristics of the home and property we can use the "Opposites Attract" rule-of-thumb for laying out the spaces. For instance, if a home is to be built upon a fully open lot void of all trees and structures then this type of passive planning strategy is most effective. As mentioned previously, the kitchen and utility area of a home is the warmest part of the home so by placing it in the much cooler northeast portion of the site it will help to naturally balance and contribute to the heating requirements of the home.

For the coolest part of a home which, in general, is the bedroom it can be passively warmed by placing it on the warmest part of the lot in the southwest portion. The sun exposure coupled with the heat of the day will also help to naturally balance and contribute to the heating requirements of the home.

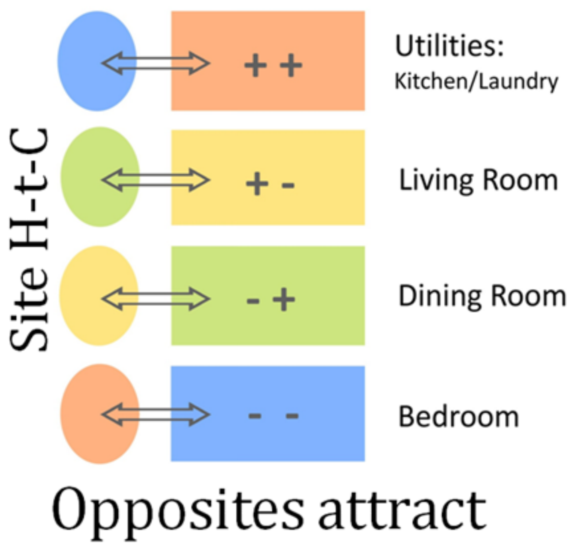

Figure 23. Desired home thermal programming

Solar orientation and massing of the home building is critical to maximizing the potential benefits of proper thermal planning. The various orientations are depicted in the following graphic with the East-to-West orientation being the most preferred for thermal balance, not to mention maximizing the contribution of sun light for lighting the interior of the home in a controllable way. In reality, the orientation of many homes are dictated by other needs such a land form and topography, views to a special amenity such as a lake or green space and street or property alignment. However, for new homes or major renovations the orientation does not have to preclude the potential for a home to have a beneficial thermally balanced layout. As you can see in the various orientations in the following graphic *(figure 24)*, the hot spaces can still be located at the cooler northeast portion of the site and the cooler spaces can be located in the warmer southwest location. Careful observation and planning and can help to assist in building a lower energy and more comfortable home, or neighborhood.

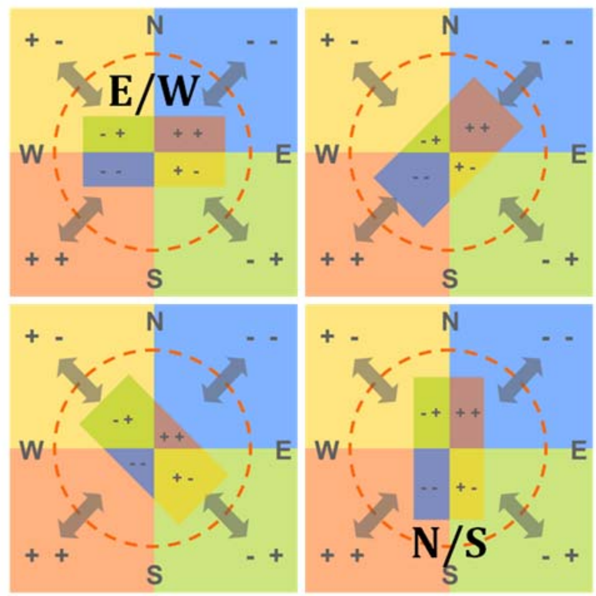

Figure 24. Four orientations with house thermal layout

The following graphics *(figures 25 and 26)* depict four case study homes in four of the CONNECT participating counties. Two were from counties in South Carolina and two were from counties in North Carolina. As you can see, the orientation and massing of the homes vary from compact to linear and from northwest facing to due east facing. This is a typical finding throughout neighborhoods across our region, regardless of urban or rural location.

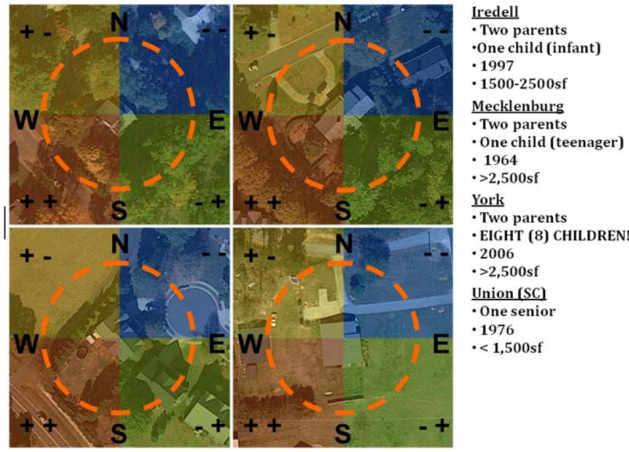

Figure 25. Four study homes with site thermal

As we studied the homes and provided a simple color coded thermal overlay over each home to reflect where hot-to-cold spaces are located we begin to see that there is a mixture of space layouts from home to home. Although none of these homes are ideally planned according to purely passive planning measures the top two do benefit from external deciduous tree shade on the southwest portion of the site as this is where the hottest part of the homes are located.

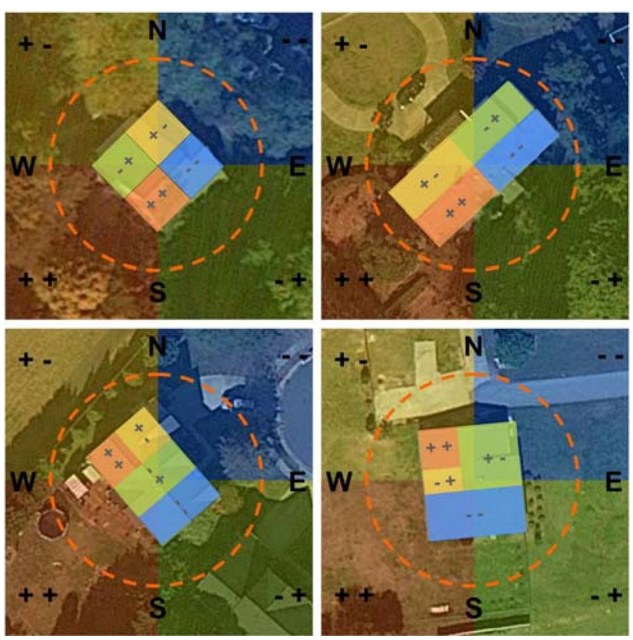

Figure 26. Overlay of existing home and site thermal relationship

The other two home sites are more exposed and void of adjacent tree shade which has presented not only an increase in summer heat gain but also in low-angle sun light glare during the evening hours. One home uses interior window shades to mitigate the heat and glare and the other benefits from an external porch overhang.

Figure 27. Do not pair like thermal spaces

As a general planning rule for reducing the external thermal temperature negative impacts on a detached single-family home carefully plan for the "Opposites Attract" layout. If this cannot be achieved to the fullest extent then observe where potential exterior shading or sun exposure may be and either allow the sun to warm cooler spaces via windows or block the sun out of warmer spaces in the summertime heat.

We're finding **THERMAL IMBALANCE** from a basic planning perspective.

Each home will vary in its size, location and spatial layout but by following a set of planning principals to reduce the burden of unwanted heat or sun light glare the home's energy performance and homeowner comfort can be dramatically enhanced.

Diagnostics Testing

Two diagnostic tests were provided to participating homeowners to measure actual physical airflow characteristics of the home building and HVAC system. The Blower Door Test *(figures 28 and 29)* measures the air tightness of a building by using a calibrated sensor under a predetermined air pressure setting and a fan with known airflow capacities. The fan pulls air from the interior of the home to the outside and measures the airflow against that known pressure. The differences in recorded air pressure at a known air flow rate determine the levels of air tightness of the building.

Figure 28. Common areas of air leakage in building envelope

Acceptable levels of air tightness vary between existing homes and will depend on the complexity of the building construction, access to areas in need of sealing and percentage of determined air losses. As the difficulty to seal remote openings in constricted areas increase so does the cost to do so and this increases the payback period for the investment. The homeowner may opt for less than a complete air sealing due to this increase in cost and payback time. A home that is already relatively air tight may not be a good candidate for air sealing as the benefits likely may not outweigh the costs. A home that has a high level of air infiltration with good access to the leaking areas will benefit the most as the payback on the air sealing activities will occur at a much quicker rate of time and the comfort of the home can be dramatically improved.

Figure 29. 'Blower Door' diagnostics test underway

The Duct Blaster Test *(figure 30)* is the second diagnostic test performed for the homeowners and, similar to the Blower Door test, it measures air tightness of a home's HVAC ductwork. As homes age the ductwork connections can work loose or be damaged from attic or crawlspace usage and send conditioned air into spaces that are not intended for conditioning, your attic or crawlspace. Old ductwork that was originally sealed tight at the connections may have deteriorated tape and mastic joints that are in need of scraping, cleaning and resealing.

A Duct Blaster test also uses a calibrated fan and known air pressure to move air through a home's system of ductwork with a sensor to calculate the differential in air pressure at a known air flow rate. All of the home's air supply and return air grilles are blocked off while airflow is increased throughout the ductwork until a preset air pressure is reached. The more air flow rate that it takes to reach this desired air pressure reading the more leaks the ductwork system will likely have.

Figure 30. 'Duct Blaster' diagnostics test underway

Like the air sealing of the building, the air sealing of the ductwork can be complex and inaccessible. Ductwork built within the walls of the home may leak but the cost to tear into a wall for air sealing the duct may heavily outweigh the payback period of air sealing. Also, ductwork that is subject to moist and warm conditions commonly found in crawlspaces throughout the southeast may not hold a tight seal over time due to chances of increased degradation. In this case, the cause of wet and warm crawlspaces should be addressed first prior to engaging a duct seal activity.

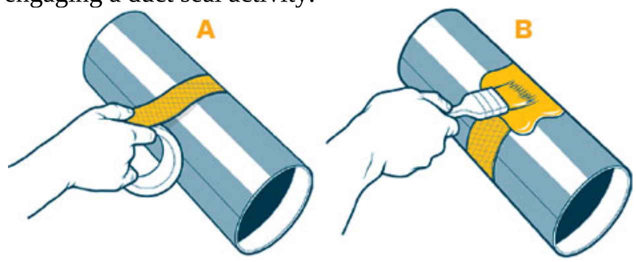

Figure 31. External duct sealing with tape and mastic

Where the percentage of air losses in the ductwork is within reasonable standards the homeowner may opt to invest elsewhere in their home to affect greater and more immediate energy savings. Where the percentage of air losses in the ductwork are well above acceptable norms and access to the ductwork is easily available the homeowner will benefit greatly by having their ducts sealed either internally or externally.

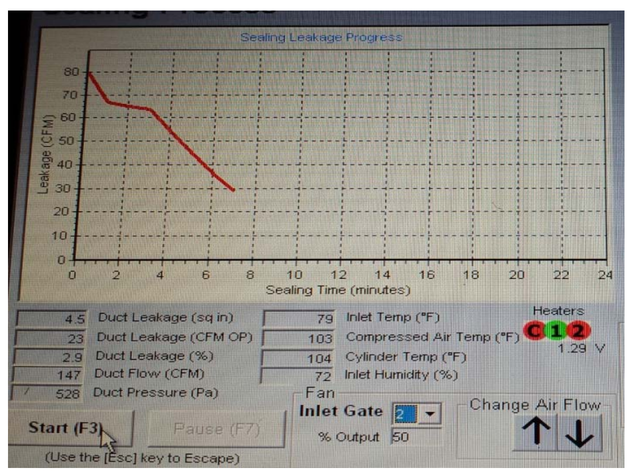

Figure 32. Screen shot of Internal Duct sealing underway. The red line indicates air leakage (CFM) decrease as the sealing activity progresses.

Audit Report

In addition to the two diagnostic air tightness tests a home's physical characteristics including age, type of construction, solar orientation, square footage, number of stories, wall area square footage, window area, and thickness of insulation can be entered into a software program that models the home against the utility bill history to assist in highlighting modeled energy consumption as compared to actual energy usage as determined in utility bills. Where large discrepancies are found they serve as indicators for areas of potential improvement.

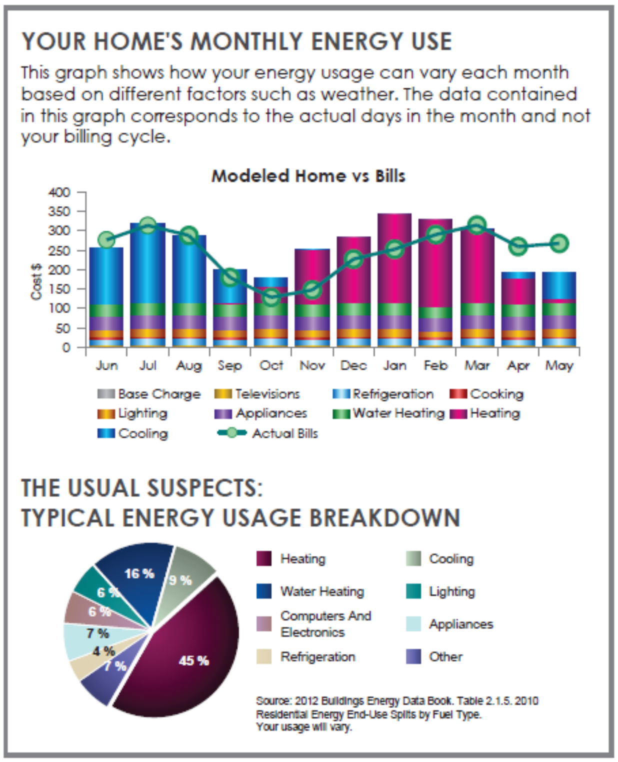

Figure 33. Modeled Energy Use compared to actual utility bills

The energy audit report produced out of the case study audit activities provides the homeowner with several graphical and chart based metrics in which to better understand their homes performance. The area of air leakage found by the Blower Door test can be shown in units of square inches. As a size comparison, a sheet of standard 8.5" x 11" printing paper is 93.5 square inches and many homes may have a few thousand square feet of roofs, walls and floors. Although the area of a sheet of paper may sound miniscule in comparison to the area of a building envelope it is important to see how the leakage area actually occurs in the home.

For comparison, if you take the sheet of paper and cut it into strips that are 1/16" of an inch in width then place these strips end on end and measure the full length you will have a thin strip of paper that is 125' long. This represents the potential length of cracks between building materials such as brick siding and wood windows or drywall and concrete. These cracks are not large but their impacts on air losses are great.

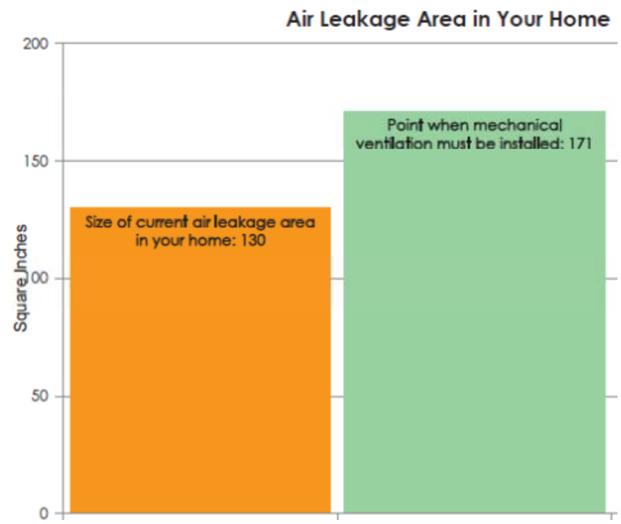

Figure 34. Area of air leakage found in an energy audit

An improvement package *(figure 35)* is also provided within the audit report and it lists multiple items such as HVAC thermostats, water heater and insulation that could be upgraded and shows the projected improvement performance. The baseline shows the current use of the home and the "Improved" column lists the recommended changes. Most notable are the zero cost items such as lowering the temperature set point on the HVAC thermostat, refrigerator and water heater. The goal here is to adjust the temperature settings by a small margin, a degree or two over time and determine if the comfort and performance is acceptable or not. If it is still comfortable and performs well with the adjusted settings then adjust them by another degree or two until you reach your optimum comfort and performance level within the most efficient setting. *Caution should be taken when raising the temperature in a refrigerator and freezer as the proper temperature for stored food items will govern how much temperature adjustments can be made. Refer to your owner's manual.*

Improvements	Base	Improved
Thermostat	68 Deg.	64 Deg.
Refrigerator	1,425 kWh	885 kWh
Reduce water use	100% of Avg.	75% of Avg.
Insulate attic	R=22.4	R=43.4
Duct/Pipe Eff	Eff.=87%	Eff.=90%

Figure 35. Sample of "Improvement" options from Audit Report

When considering adjustments to the HVAC thermostat settings it is important to know what the Relative Humidity Percentage (RH%) is in the home. The higher the percentage, say RH60 or above, the more likely one is to notice smaller temperature swings within the home as the moisture in the air magnifies our senses. This higher RH% can also be a problem for the home building as well causing condensation and expansion of building materials not to mention the potential for mold growth. The lower the RH%, say RH50 or below, the dryer a space will feel and potential discomfort may occur as well. The home building can be negatively affected as well where building materials, finishes and furnishings may contract and crack where joined together.

Although it ultimately depends on personal comfort levels, a common RH% that provides the most benefit in comfort and building durability falls between RH50-60 with RH55 being an optimum goal. A home's HVAC system is as much or more so, a system to control the humidity levels in a home as it is to control the temperature levels. By maintaining a constant RH55 the cooling and heating temperature in a home can be raised higher in the summer time or lower in the winter time with much less noticeable discomfort. When the RH% dramatically increases or decreases the change in temperature becomes quickly noticeable and discomfort sets in.

One term in the HVAC industry is "Short-Cycling", that is, when a HVAC system runs for frequent but short periods of time. In order for the HVAC system to maintain constant control of the humidity levels in a home it needs to run for less often but longer periods of time. A properly sized and operating HVAC system will fully exchange the air in home through its air handler and help to dehumidify the air as well. The shorter blasts of air during short-cycling do not allow for this full exchange of air thereby allowing the humidity levels in the home to be uncontrolled.

	Year	0	5	10
Current	Electricity	$1,682	$2,146	$2,739
Bill	Fuel	$1,496	$1,910	$2,438
	Total bill	$3,178	$4,056	$5,177
	Year	0	5	10
With	Electricity	$1,310	$1,672	$2,133
Package	Fuel	$1,220	$1,557	$1,987
	Total bill	$2,530	$3,228	$4,120
	Year	0	5	10
Estimated	Electricity	$372	$475	$606
Savings	Fuel	$277	$353	$451
	Total bill	$649	$828	$1,056

Figure 36. Sample of "Improvement" savings from Audit Report

The audit report also provides a projection of savings as reference to the suggested package of energy saving measures *(figure 36)*. The chart above shows the expected energy costs over a ten year period of time for the existing "as is" home and for the improved package of recommendations. It is important to consider the payback of savings over time before making a decision on upgrades. In general, a homeowner who plans to stay in the home for longer periods of time more often opts for upgrades that may take more time to payback than a homeowner who plans to relocate within a shorter time frame. Paybacks of less than five years are a good period of time for most homeowners and many upgrades like air sealing or additional insulation can meet this time frame. Upgrades such as window replacement will have a much longer payback period with respect to energy savings but may increase the market value of a home and reduce cold drafty areas of the home, thereby increasing comfort.

Duct Leakage

The average residential air duct system leaks anywhere from 20 to 30%. This is based in part on a study that was performed at Fort Drum, Jefferson County, New York military base of 2,200 existing homes and 1,400 new homes. Air duct leakage leads to millions of dollars in wasted energy across the US. The internal duct sealing is a unique process that seals your ductwork from the inside out with a non-toxic heated spray mist adhesive. Leaking ductwork leads to uneven heating and cooling which can make your home uncomfortable. Leaking ductwork can also create pressurization problems in your home that contribute to poor indoor air quality. Internal duct sealing adhesive mists are a safe alternative and effective way to seal leaking ductwork and restore system performance. This misting process was created by the Lawrence Berkley National Laboratories and has been proven to be safe and effective in thousands of homes across the country.

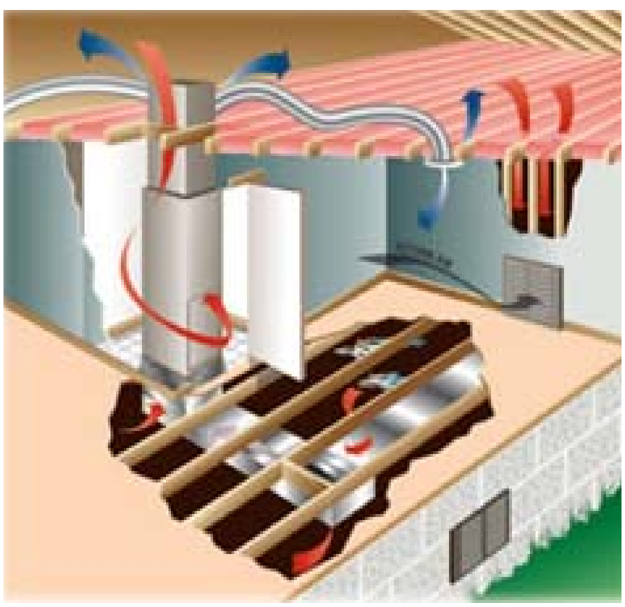

Figure 37. Common locations of air leakage In HVAC ductwork

The following "Certificate of Completion" *(figure 38)* for internal duct sealing was provided on a 1,131sf detached one story, single family case study home with all ductwork located in the attic space. The wood framed home was built in 1979 and has a two ton electric heat pump serving the entire home. Prior to sealing activities all ductwork and air handler, also located in the attic, were thoroughly cleaned with a compressed air agitator and vacuum system and sanitized with an anti-microbial application. All of the existing ductwork still had the original exterior wrapped insulation which was in good working order and only needed retaping at a few locations.

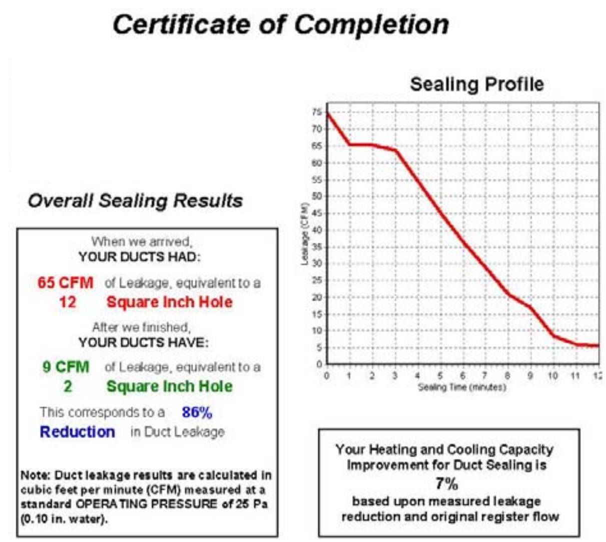

Figure 38. Internal duct sealing 'before and after' report

Also prior to the sealing activities, a pressurization test was performed on the ductwork and a leakage rate of 65 Cubic Feet per Minute (CFM) was determined which equates to a 12 square inch hole in total. This leakage area is slightly less in size than that of a 3"x5" note card and occurs at the seams of the ductwork joints. In effect, if you added up the length of seam gaps in the ductwork it would be about a 1/16" gap by twenty feet long.

As the sealing activities began the pressurization was monitored in real time and charted throughout the process which took about thirty minutes for the actual mist adhesive sealing process. The cleaning and set up time took several hours in total time. As you can see in the "Sealing Profile" of the certificate the CFM rate dropped from the 65CFM leakage rate to 9CFM at the completion. This represents an 86% seal and cut the length of the twenty foot gap to less than three feet.

Although this one sealing activity was recently completed in October of 2014 and long term utility records for before-and-after comparison are not yet available, the air flow in the home has been significantly increased providing thermal coverage in areas that previously were known to be lacking. One item of note, with the increased volume of airflow the sound of the air being pushed through the supply grilles increases as well. This is a clear indication that much more conditioned air is now entering into the conditioned home versus being wasted into the unconditioned attic space and to the outside environment. Although every home will vary in the initial leakage rates and final seal percentages this one house example is representative of the potential benefits of air sealing in HVAC ductwork systems.

The following graph represents CFM leakage rates prior to and after internal duct sealing activities for twenty nine homes in the CONNECT region. The graph shows that the average leakage rate for this sampling is 90.3CFM

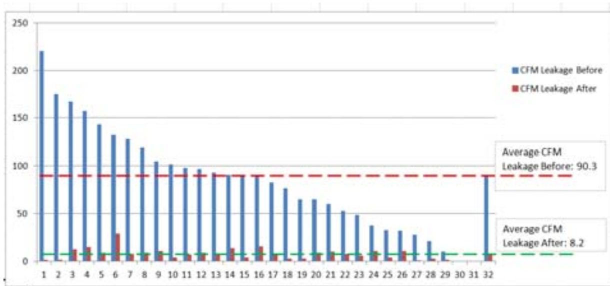

Figure 39. Internal duct sealing 'before and after' data

prior to any sealing activities and 8.2CFM afterwards. This is an 88.7% reduction in gaps throughout the thousands of feet of installed ductwork in these homes and substantially reduces the conditioned air losses to unconditioned attics and crawlspaces. Also, the equivalent hole size reduction is shown in the following chart *(figure 40)* and shows that the average hole size was 17.1 square inches prior to sealing and was reduced to 1.6 square inches afterwards.

Aeroseal Data - Fresh Air Technologies, Inc. (Compiled by GREENTHINC., PLLC)						
House No.	Zip Code	CFM Leakage		% reduction	Hole Size (Sq. In.)	
		Before	After		Before	After
1	28211	220	2	99	42	0
2	28027	175	2	99	33	0
3	28117	167	13	92	32	2
4	28112	157	15	90	30	3
5	28034	143	9	94	27	2
6	28112	132	29	78	25	5
7	28211	128	8	93	24	2
8	28226	119	9	93	23	2
9	28226	105	11	90	20	2
10	28134	102	4	96	19	1
11	28226	98	7	93	19	1
12	28205	97	9	91	18	2
13	28027	93	7	93	18	1
14	28277	91	14	85	17	3
15	28270	90	4	95	17	1
16	28277	89	16	82	17	3
17	28173	83	8	90	16	2
18	28207	77	3	96	15	1
19	29732	65	3	95	12	1
20	28227	65	9	86	12	2
21	28227	60	10	84	11	2
22	28036	53	8	84	10	2
23	28034	49	6	89	9	1
24	28112	38	11	70	7	2
25	28211	33	4	87	6	1
26	28207	32	11	66	6	2
27	28075	28	1	95	5	0
28	28210	21	3	87	4	1
29	28273	10	2	79	2	0
Average		90.3	8.2	88.7	17.1	1.6

Figure 40. Internal duct sealing 'before and after' data

The payback period for the example home is still under review and as it is recently completed sealed ductwork. For this home in particular in 2014, there were various prices to achieve the cleaned, sealed and insulated ductwork ranging from $800 for fully insulated and clean ductwork replacement by a local HVAC company, to $400 for full cleaning only to the existing ductwork, to $900 for cleaning and internal sealing. It will always be up to each homeowner to determine the final services that they are in need of, the price that they are willing to pay for those services, and the comfort level that they have with the HVAC cleaning and sealing providers prior to executing any HVAC sealing and cleaning activities. In the end, the primary goal is to increase the comfort of the people in the home while reducing long term and reoccurring utility costs.

Utility History Assessment Summary

A database has been created based upon energy data collection and performance assessment information collected by partner organizations and shared with the NEPDEER team for this project.

Data from the partner organizations was combined with:

- Historical utility information (1 year previous to application) from completed Homeowner Application Forms. (40 homes)
- NEPDEER Audit data (30 homes)
- NEPDEER Monitoring Data (10 homes)

Partner organizations included:

City of Charlotte Neighborhood Energy Challenge

Habitat for Humanity Charlotte Critical Home Repair

Goodwill Construction Industries

Efficiency First Solutions, LLC

Builders of Hope

The aggregation of information into the database revealed a significant variability in the home assessment and documentation process. This process resulted in the following observations:

- There is a lack of standardization in the industry
- This lack of standardization hampers the ability for assessment agencies to leverage the information gathered and undermines the credibility of their efforts as an industry.
- Because actual energy use can vary widely from estimated building performance due to fluctuations in activity levels, weather and number of occupants, even efforts to standardize have been undermined by inconsistent results.

Audit information and Historical data information for the NEPDEER homes showed that the behaviors of the occupants had a much larger impact on the amount of energy used in the home than the physical attributes of the structure, or the efficiency of the installed equipment.

EPA Yardstick

The EPA Yardstick tool has been developed to normalize the inherent fluctuations in energy use based on occupant load, weather and typical (statistical average) use.

During the assessment of the energy data, the methodology employed by the Environmental Protection Agency in the online yardstick widget was integrated into the metrics for the NEPDEER homes.

Figure 41. EPA Yardstick Score Graphic

Energy Information Agency

Regional data available for single family homes from the Energy Information Agency gives a statistical perspective in terms of average use per occupant (measured in mbtus/sf/yr) and average energy use per square foot of dwelling (measured in kbtu/sqft/yr)

The data collected for the NEPDEER homes was formatted to relate to this information.

Example Properties and Neighborhoods

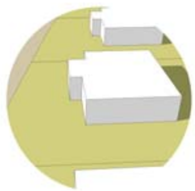

Figure 42. Example Property 1 - Front orientation SW

Size of Home:	3,409	Square feet
Year Built	2006	
Number of Occupants:	10	people
Total Energy:	104,254	kbtu
Baseload Energy:	47,464	kbtu
Heating Energy:	43,718	kbtu
Cooling Energy:	10,072	kbtu
Energy Use Intensity;	31	kbtu/sq ft
Energy per occupant	10	mbtu/person/yr
EPA YARDSTICK SCORE	9.5	
NEPDEER audit	2415	CFM lost

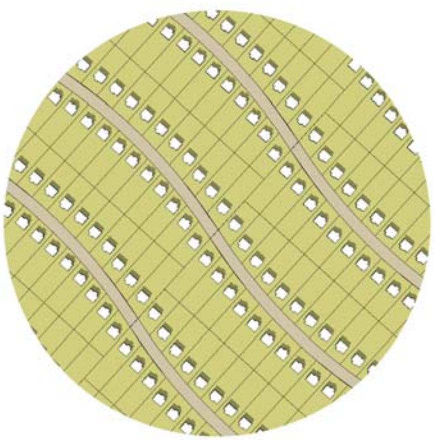

Figure 43. Example Neighborhood 1 - SW axis curvilinear streets large lots

Figure 44. Example Property 2 - Front orientation SE

Size of Home::	1,939	Square feet
Year Built	1,986	
Number of Occupants:	3	people
Total Energy:	73,318	kbtu
Baseload Energy:	34,996	kbtu
Heating Energy:	33,100	kbtu
Cooling Energy:	5,222	kbtu
Energy Use Intensity;	38	kbtu/sq ft
Energy per occupant	24	mbtu/person/yr
EPA YARDSTICK SCORE	9.5	
NEPDEER audit	4500	CFM lost

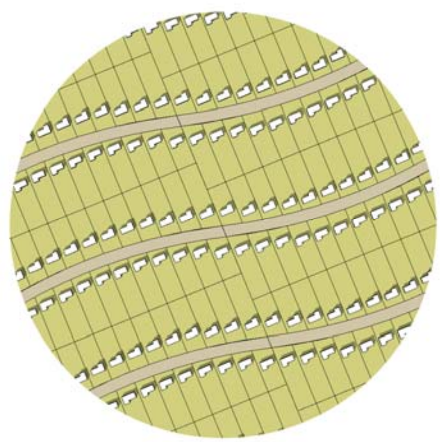

Figure 45. Example Neighborhood 2 - SE/NW axis curvilinear streets large lots

Example Properties and Neighborhoods (cont)

*Figure 46. Example Property **3** - Front orientation E/NE*

Size of Home:	1,016	Square feet
Year Built	1949	
Number of Occupants:	2	people
Total Energy:	72,986	kbtu
Baseload Energy:	31,573	kbtu
Heating Energy:	37,206	kbtu
Cooling Energy:	6,207	kbtu
Energy Use Intensity;	74	kbtu/sq ft
Energy per occupant	37	mbtu/person/yr
EPA YARDSTICK SCORE	5.0	
NEPDEER audit	3243	CFM lost

Figure 47. Example Neighborhood 3 - E/W axis perpendicular streets small lots

Figure 48. Example Property 4 - Front orientation E

Size of Home:	1,229	Square feet
Year Built	1,988	
Number of Occupants:	2	people
Total Energy:	52,350	kbtu
Baseload Energy:	24,187	kbtu
Heating Energy:	26,472	kbtu
Cooling Energy:	1,691	kbtu
Energy Use Intensity;	43	kbtu/sq ft
Energy per occupant	26	mbtu/person/yr
EPA YARDSTICK SCORE	9.5	
NEPDEER audit	1521	CFM lost

Figure 49. Example Neighborhood 4 - E/W axis curvilinear streets medium sized lots

Home Utility Data

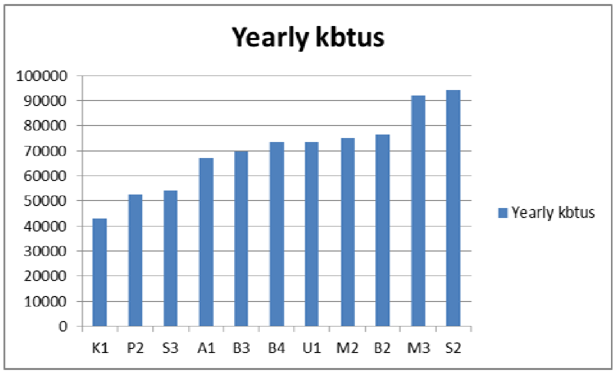

Figure 50. 2 person dwellings: ranked lowest to highest: Total energy use in thermal units

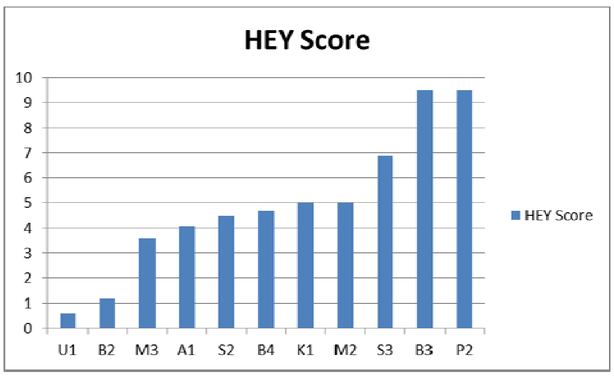

Figure 51. 2 person dwellings: ranked lowest to highest: EPA Yardstick Score

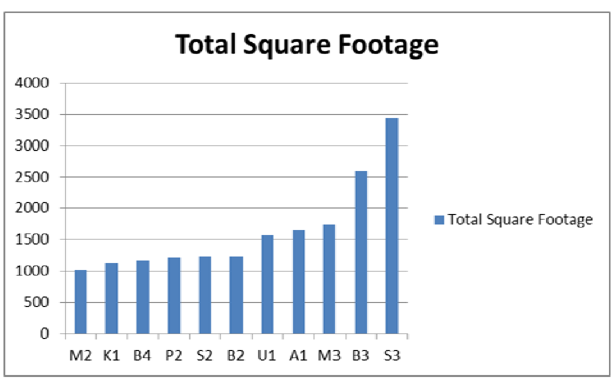

Figure 52. 2 person dwellings: ranked lowest to highest: Size of dwelling unit

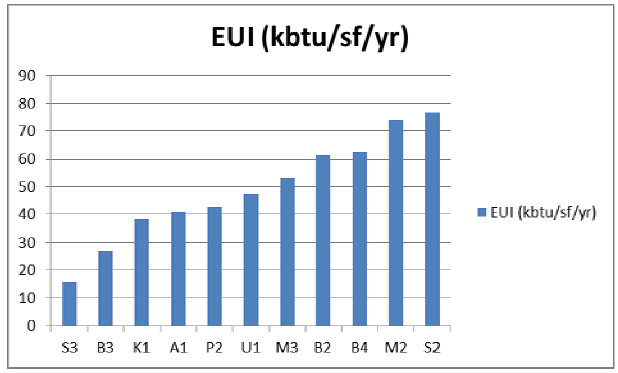

Figure 53. 2 person dwellings: ranked lowest to highest: Energy use per square foot per year

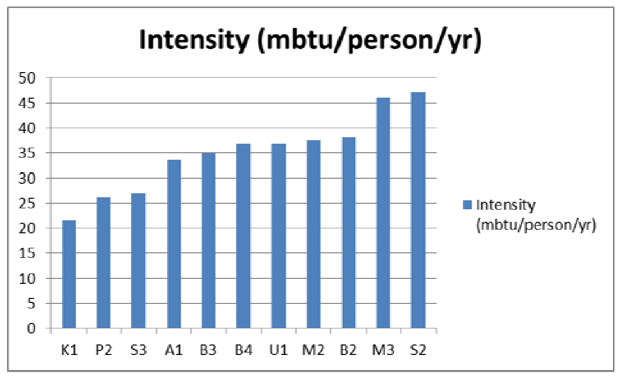

Figure 54. 2 person dwellings: ranked lowest to highest: Energy use per person per year

Key Findings Overview

Non HVAC loads and Heating Loads dominate the yearly energy use.

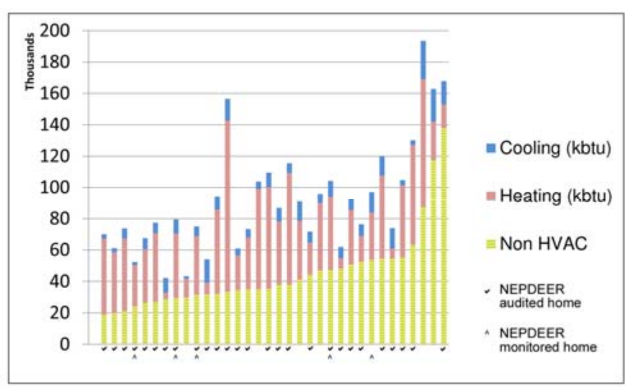

Figure 55. Historical Energy Use 1 year sample

In-Home Energy Monitoring

This energy study project provided and installed a package of energy monitoring equipment *(figure 56)* into several of the participating homeowner's electrical panels and started recording energy use data in the home HVAC equipment and various zones such as the kitchen or living areas. The data was recorded in multiple time intervals ranging from every second to daily and monthly use. Direct and real time feedback was provided by the software dashboard and the homeowner was able to witness their energy use as it occurred. This direct information not only served our project goals of data collection well but also informed the homeowner where daily energy use efficiencies could be made and where potential problems may exist in their home's equipment as noted via abnormal energy spike recordings.

Figure 56. "TED" The Energy Detective: Energy monitoring package with sensors and dashboard display

Each home that we installed the equipment in varied in location, age, size, number of occupants and spatial layout. For example, one 900sf home only had one disabled senior occupant while another 3,400sf home had a family of ten including eight children. The comparison of energy use per occupant and square foot for specific equipment or spaces is made available by this level of data monitoring and provides insight on the differing uses of the homes primary spaces and equipment. Having data taken on a daily basis is useful when comparing to traditional metrics of the outdoor environment such as temperature in the heating or cooling season. Heating Degree Days (HDD) or Cooling Degree Days (CDD) is a historical average of temperature in a specified region compared to a baseline temperature of 65 degrees Fahrenheit. Colder regions have much higher HDD value than CCD and, conversely, hotter regions have much higher CCD value than HDD. We are comparing the data taken against these values for the participating homeowner locations to see the actual changes of the local weather temperatures as compared to five year averages *(figure 57)*.

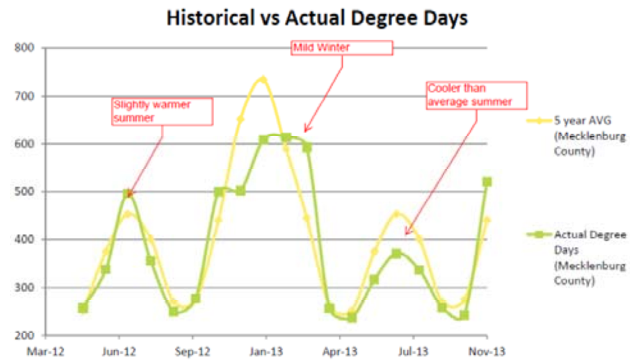

Figure 57. Historical Degree Days vs. Actual Degree Days

In addition to the homeowner being able to monitor their current actual energy use they were able to monitor the changes that they made in the use of their home such as reducing their HVAC temperature set points or water heater temperature over time. Additions of new electronics or replacement appliances can also be impactful and potentially detected by the monitoring equipment, depending on how it is configured.

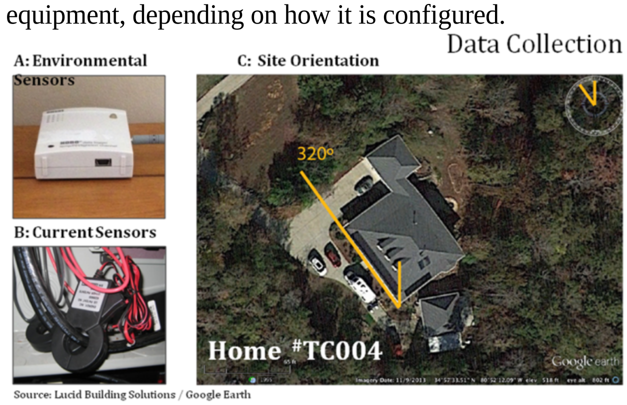

Figure 58. Environmental and electrical sensors

The following graph *(figure 59)* depicts the monitored power cycle of an HVAC system between the months of July and October 2014. As can be validated by the decrease in monitored operational time the exterior temperature also decreased as the fall season approached.

Although the reason for this decrease is obvious, it is important to note that the operation of the HVAC system is seasonally affected and the cooler temperatures of the fall and spring allow for the house to reach a balanced temperature without mechanical assist.

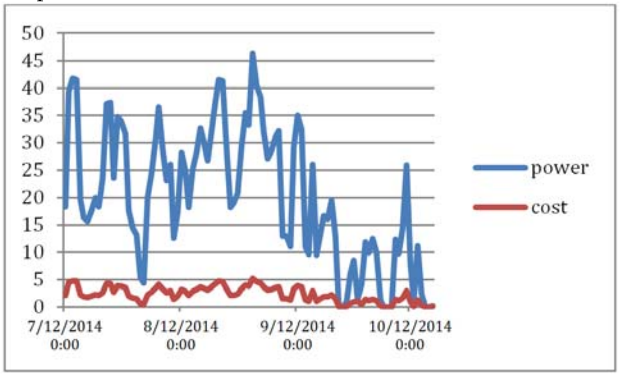

Figure 59. HVAC daily monitored use

Unlike the seasonally affected HVAC equipment in the home, appliances such as a clothes dryer is part of the home's base load energy uses and is used consistently throughout the year, regardless of exterior temperature. As can be seen in the following graph *(figure 60)* a repetitive pattern of use was monitored in one of our participating homes and a few spikes of energy consumption represent heavy use and/or potentially blocked exhaust vents. Similar to the energy consumed in domestic water heating, the clothes dryer is often found to be a common source of excessive energy consumption

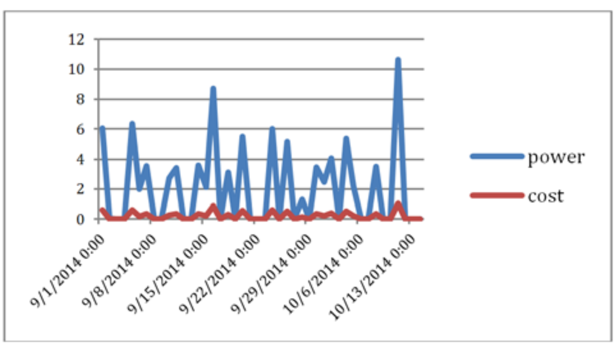

Figure 60. Clothes Dryer daily monitored use

due to constricted air flow at the lint filter and within the exhaust ducting to the exterior. Rules of thumb for the most efficient clothes dryer energy use include reducing the length and transitions of exhaust venting, using frictionless smooth piping for venting, and thorough washing spin cycles to minimize the amount of moisture in the clothing. A common maximum length of 30-35 feet for exhaust venting can be acceptable with exception when interrupted by transitions. Where transitions are unavoidable, such as a ninety degree elbow, deduct five feet for every transition for effective air flow. The maximum exhaust vent length with three transitions will be reduced to 15-20 feet overall so plan accordingly.

Figure 61. Energy Monitoring Dashboard

As can be seen in the dashboard graphic *(figure 61)* the energy consumed in the home can be represented in several measures. The peak usage of a specific time and day is easily accessed and the "speedometer" of the home's energy use is represented in a dial format showing real-time KW usage. A homeowner can experiment by powering up or down certain components or spaces in the home and see in real time how it affects the total KW consumption. Energy unit cost can also be recorded and used as a back up to compare the end of month utility bill against. All of this information can be downloaded for long term record keeping and revisited annually to check on the progress of energy conservations measures that may have taken place in the home.

Section 3 – Findings and Recommendations

Passive Thermal Planning

Where the opportunity exists during a major renovation of an existing home, and certainly when planning a new home or neighborhood, passive planning strategies *(figure 62)* can help reduce energy consumption and increase comfort to home's occupants. Since the detached single-family home is directly affected by the external temperature, humidity, wind and solar access incorporating the principles of passive design early in the planning stages will lead to low-to-no-cost solutions such as optimum solar orientation and strategic spatial layout of the home's interior.

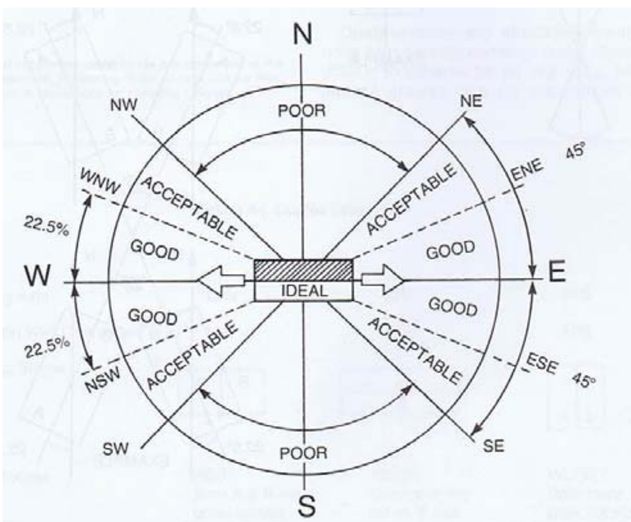

Figure 62. Solar orientation template; Site Planning For Solar Access: A Guidebook for Residential Developers and Site Planners

The Rule-of-Thumb for passive interior planning considers the hot and cold spaces and how solar exposure or shading can be of beneficial use. When possible, plan for the warmer spaces, such as the kitchen or laundry room, to be located on the coolest portion of the site or to be shaded by adjacent structures or trees during the cooling season. Conversely, plan to passively warm the cooler spaces, such as the bedroom, by allowing for sun exposure during the heating season.

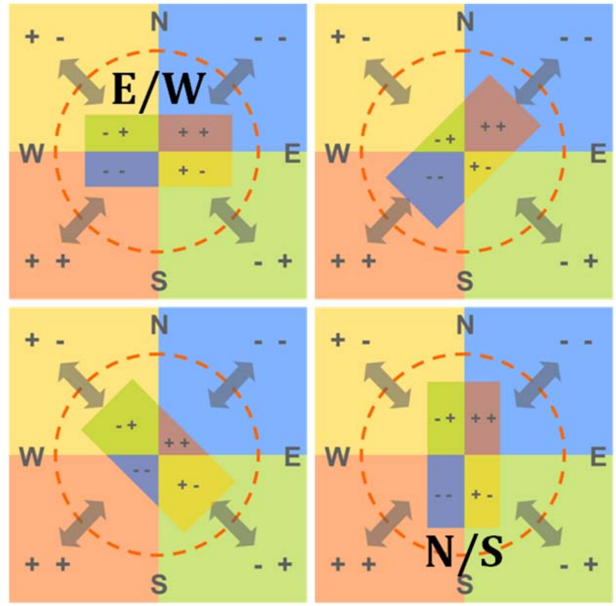

Figure 63. Four orientations with house thermal layout

Landscape and Shading

An option available to existing and new homes to passively cool homes is in using tree shade to block out unwanted summertime sun light in warmer spaces and also to allow for low angle sunlight penetration for spaces than can benefit during the winter time. Deciduous trees will allow for winter sun exposure by the loss of leaves but will shade the space from harsh summer sun penetration along with uncomfortable glare.

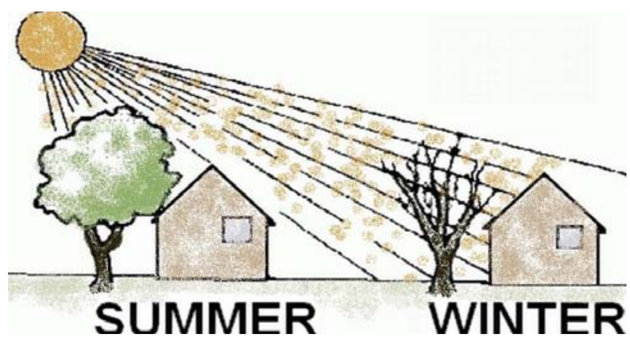

Figure 64. Shading for cooling and heating on the southern façade

Care should be taken when locating trees close to structures due to root growth and limb deterioration. Maintaining tree health is required in order to ensure the long term shading function and natural contribution of carbon sequestration provided by trees.

Air Sealing

The most common issue found in the audit test activities in all homes regardless of age, size, cost, orientation or interior layout is air infiltration and losses due to poorly sealed roof, wall, floor construction joints and penetrations as well as HVAC ductwork joints.

Figure 65. "Keep filling the bucket?"

Homeowners have options to them to for detecting and resolving leaky areas of their home. The DIY type of homeowner can use a caulk gun and seal the accessible and apparent locations. Other homeowners may opt for hiring a weatherization company to assess their home through diagnostic testing such as Blower Door and Duct Blaster tests.

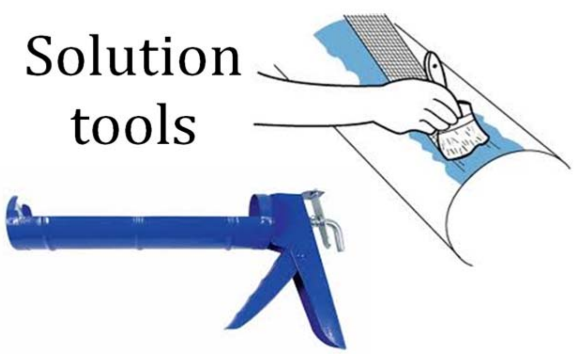

Figure 66. Simple tools to fill the gaps. The caulk gun for the building envelope gaps. Tape and mastic for ductwork gaps.

Most weatherization companies also provide sealing activities so care should be taken when receiving reports as to considering the actual need for air sealing. Multiple quotes should be solicited prior to hiring a company to test for and air seal the home.

Sealed attics and crawlspaces have gained in popularity over the past ten years in our region as the building science community has demonstrated the benefits of air sealing the total home envelope versus only the floors, ceilings and walls. Traditional home construction utilizes natural air flow in crawl spaces and attics for continuous ventilation. Crawl space and attic eave vents *(figure 67)* have been partly effective in keeping temperature and moisture at moderate levels but do not provide full control of those environmental variables. The primary differences between the old and new methods are in where the insulation and moisture barriers are placed in the building envelope, how the air in a crawlspace and attic is conditioned, and the additional performance requirements of the HVAC mechanical system.

Figure 67. Traditional vs. Sealed Crawl Space

Similar to sealed crawl spaces, the air sealing of an attic includes placing the insulation, usually spray foam, in the roof rafter location instead of in the ceiling joist cavity. The goal of air sealing an attic is to fully enclose the building envelope and reduce the swings in temperature and humidity adjacent to the living area. A soffit to roof ventilation path is still required to keep the roofing cool and can be accommodated by installing ventilation baffles under the roof sheathing and applying the insulation to the underside.

Figure 68. Air sealed attic space

An additional benefit of air sealing attics and crawl spaces is in the performance of the HVAC equipment and ductwork as this is where they generally located. This decrease in temperature and humidity swings puts less stress on the equipment and conditioned air moving through HVAC ductwork. It is important to note that for sealed crawl spaces and air sealed attics containing equipment they must be reviewed for proper ventilation, carbon monoxide detection and backup power plan prior to performing any type of sealing activities.

Insulation

Once the areas of air infiltration have been addressed and resolved many homeowners my benefit from proper insulation in the roof, walls and floors of the home. Accessibility to all areas in need of insulation plays a role in how effective the insulating activity will ultimately be. The ceiling/roof and crawlspaces are generally the most accessible spaces to assess the quality of existing insulation. Existing walls covered in drywall are the most difficult and cost prohibitive part of the home to maximize the insulation levels. The exception to this may be in older homes that did not have insulation installed originally. The reduced cost to heat or cool those homes along with the increase in occupant comfort may achieve an acceptable payback period over the increased cost to repair walls that have been partly demolished to allow for the new insulation.

Figure 69. Addition of Blown-In attic insulation

An alternative to demolishing wall finishes to insulate existing walls is an injection foam insulation process that uses an expandable foam blend injected into a series of small penetrations made into the exterior wall *(figure 70)*. While not a commonly used practice in the weatherization of existing homes and higher in initial cost as compared to traditional insulating services it does provide for a much better thermal envelope with minimal damage to the existing wall construction. When determining if the cost is acceptable, the cost of wall repair from traditional demolition, insulation and finish replacement must be considered as well as the amount of time to complete the work.

Figure 70. Injection Foam Insulation retrofit in an existing home

Similar to the injection foam insulation is the expandable spray foam application that provides a very good coverage of roof, wall, and floor cavities. There are two types of expandable spray foam to choose from, open-cell and closed-cell, and each is suited for certain performance applications. Open-cell spray foam insulation is most commonly used and serves general insulation needs very well while reducing air infiltration and sound transfer. Closed-cell spray foam insulation not only provides for superior insulation, reduced air infiltration and sound attenuation but acts as an added moisture barrier and increases the structural integrity of the building as a result of its rigidity in set up. Closed-cell spray foam is best suited to areas of increased moisture such as a basement or crawlspace or in regions of high humidity. Care should be taken when applying spray foam as its expandable characteristic has been known to cause warping or bowing at window and door openings. Contact a local weatherization company to find out more.

Figure 71. Spray-foam Insulation into a wood stud wall cavity

Right-Sizing, Balancing & Maintaining HVAC Equipment

The "engine" of a home, the HVAC system, is often taken for granted and not maintained on a regular schedule. This can lead to inefficient operation costing more to run and increasing stress on system parts potentially leading to shorter a life span of the working parts. Similar to the routine maintenance schedule that we set up for our automobiles the HVAC system should be on a reoccurring maintenance program for the changing of seasons and general upkeep.

Figure 72. Trane Variable Speed Air Handler

When time for upgrades or replacement come due for HVAC systems care should taken in selecting a service company that will not only provide the correctly sized system for a home but also provide for a balancing of the system once it has been installed. Many HVAC systems are oversized which can lead to the short-cycling of conditioned air supply negating the controllability of humidity within the home, a cause for discomfort. Options to alleviate short-cycling problems may be resolved by adjusting air handler fan speed or installing a variable-speed fan at the air handler. This will ultimately need to be discussed with a service provider for the proper end solution. Again, a properly sized HVAC system will run for longer periods of time at a slower rate which allows for full air changes throughout the home. This is where the controllability of humidity takes place to a much better degree than through short-cycling.

Return air filters are also important to maintain on a regular schedule and installing the proper filter is critical to efficient air flow from the air handler. There has been an increase in heavily pleated filters in the marketplace stating that their increased filtration capability is more beneficial to higher quality indoor air. While there is no argument against increased filtration and air quality benefits there is a downside to using heavily pleated filters in return air locations. They are the cause of a pressure drop and increased stresses at the air handler fan as the air flow is more restricted - imagine trying to breathe through a thick blanket. The primary purpose of the return air filter is to minimize the collection of dust from within the air handler itself.

Figure 73. MERV 7 Pleated Air Filter

The blue and green "builder" grade fiberglass filters allow for the greatest air flow but they also allow for the greatest amount of dust to pass through and into the air handler. The filter that provides the greatest balance of air flow and dust filtration is the softly pleated "cottony" type of filter *(figure 73)*. If air filtration is needed in the home due to allergies of other sensitivities it is advisable to invest in a dedicated air filtration system separate from the air handler system.

Windows

One of the greatest single expenses considered when renovating or upgrading a home is in window replacement. Homeowners often consider new windows prior to air sealing the building and ductwork, added insulation or proper operation of the HVAC system. While windows are indeed the weakest thermal parts of any wall construction they are not always the best priority for decreasing energy use in the home. More often than not, drafty windows are due to poor seals at construction openings, not necessarily the window itself. This is where backer rod and sealant can play a significant role in reducing air infiltration *(figure 74)*.

Figure 74. Foam backer rod and sealant at existing windows

In addition to the sealing of window joints there are additional options to increasing the thermal effectiveness of the window assembly. One such option is an internal magnetically attached glass pane insert that is fitted to the size of the existing window and attaches onto the frame for an air tight seal *(figure 75)*.

If full window replacement is required due to damaged glazing, broken insulated seals, or water damage consider thermally-broken, double or triple insulated glass units with argon gas filled air space and selective low emissive (Low-E) surface treatment *(figure 76)*. The thermal break will stop temperature migration from entering into the interior of the frame where potential condensation may occur. The double or triple glazing insulated units will provide a greater layered level of thermal protection as well. The argon gas filled air space provides an additional layer of thermal protection as it does not transmit temperature as well as air does and acts to stabilize the temperature transfer at the window glazed area. The Low-E surface treatment is a sputter-coated treatment to the inside surface of one of the glass layers that resists UV light from the exterior while reflecting the interior heat back into the home during the winter season.

Figure 75. Internally magnetized glass pane Insert by Climate Seal.

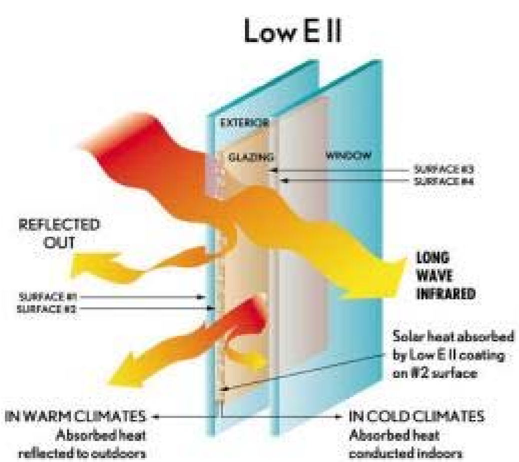

Figure 76. Low-E coated, thermally insulated glazing

Radiant Barriers

Radiant barriers are primarily installed in a home's attic and designed to block out the heat from summer sun and reduce cooling costs. Radiant barriers are highly reflective materials, usually a lightweight aluminum product, that reflects radiant heat but do not stop thermal transfer from direct contact of other materials in the attic. Using the radiant barriers in combination with insulation materials should be discussed with a local weatherization company for proper performance prior to installation.

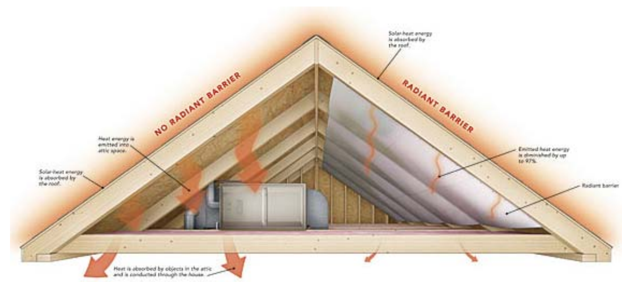

Figure 77. Radiant barrier installation vs. traditional roof

Clothes Dryer Venting

One of the simplest and lowest cost energy performance enhancements involves the proper venting of a clothes dryer exhaust. Local experts state that no more than 45 minutes should be used to dry a full load of clothes and if the load is not dry within this timeframe it is likely due to improper venting. The most efficient venting pathway is achieved by placing the dryer on an exterior wall and venting straight to the outside within a couple of feet of length with a non-combustible metal pipe duct.

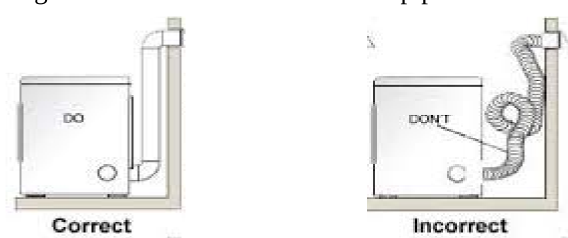

Figure 78. Dryer Venting

When venting directly to the exterior is not achievable the maximum length of the vent pipe should not exceed thirty feet in length and remain in a straight line without change in direction. For every required elbow in the vent pipe subtract five feet and this will give you the most efficient total length.

Attic Stair and Door Insulation

Most homes have either pull-down attic stairs or a hinged door into the attic area. It is important to seal these large openings with weather-stripping and insulation as the traditional attic is an unconditioned space and a major source of heat loss from the conditioned spaces below. Stopping the air infiltration with an insulating barrier is the goal.

Figure 79. Attic Stairway Insulator

Figure 80. Insulated attic doorway

The door and stair openings can be easily sealed with do-it-yourself materials such as foam tape and insulation boards and blankets or professionally installed. For pull down attic stairs a vinyl wrapped insulation blanket with adhesive attachments can be purchased from a local home center and installed easily. Another popular option is for a attic stairway insulator commonly referred to as an Attic Tent.

Lighting

While the incandescent light bulb has served a long and useful purpose for lighting our homes they have come at a cost of increased energy consumption and heat output which is a significant source of cooling need in the commercial building sector. The Compact Fluorescent Lamp (CFL) has proven to be an effective alternative to incandescent lamps with various lumen outputs and color spectrum. A 13 watt CFL can provide the same lumen output as a traditional 60 watt incandescent lamp but at a 78% reduction in electricity consumption.

Incandescent	CFL	Lumens	Cost Savings ($0.10/kWh)	Cost Savings ($0.20/kWh)	CO_2 Savings (lbs)
40W	11-12W	> 490	$39-$44	$78-$88	507-572
60W	13-18W	> 900	$62-$68	$124-$136	806-884
75W	19-22W	>1,200	$76-$83	$152-$166	988-1,079
100W	23-26W	>1,750	$107-$112	$214-$224	1,391-1,456
150W	38-42W	>2,600	$163-$169	$326-$338	2,119-2,197

Figure 81. CFL wattage comparison. www.bulbs.com

Light Emitting Diode (LED) lamps have gained in popularity and have proven to be an even more effective lighting efficiency solution than CFLs. As the popularity of LED continues the cost will continue to decrease and the technology will continue to increase. When replacing an incandescent lamp with an LED lamp consider the long term energy use reduction that LED lamps can afford. That 40 watt incandescent lamp with a projected lifespan of 1,200 hours can be replaced with a 5 watt LED with a projected lifespan of 50,000 hours. This is a 92% reduction in energy use and a 40x projected lifespan. The following chart compares brightness and efficiency of various lamp types.

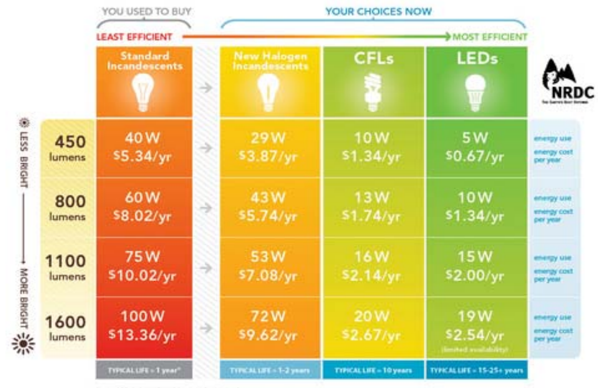

Figure 82. Lamp performance comparison. NRDC

Energy Star Appliances

The base energy load of US homes is comprised of electronics, lighting, water heating and appliances. This base load has become the largest source of energy use due to increased efficiencies of heating and cooling equipment, better building insulating construction methods, the rise of plug-load electronics and super-appliances. Our appliances are now equipped with smart technologies that can alert us when there is a problem such as low cooling temperature in the refrigerator.

When considering replacing appliances it is useful to review the Energy Star labeled appliances for choosing an energy efficient model.

ENERGY STAR

Figure 83. Look for this label on lighting, clothes washers & dryers, refrigerators, freezers, dishwashers, dehumidifiers, ceiling fans, ventilating fans, heating & cooling equipment, windows, roofing products, televisions, computer monitors, audio equipment, cable boxes and computer tablets.

Develop a maintenance schedule for all appliances to ensure continued proper operation and to extend the lifespan of the appliance. Dust collects on refrigerator coils and decreases their performance over time. Water supply hoses on clothes washers and dishwashers can deteriorate over time and replacement is a low cost solution to avoid a broken water supply line.

Water heating in the home is the largest source of energy consumption out of the base load energy uses and maintaining a properly operating water heater is essential to begin reducing energy consumption. If you have an older tank-style water heater it is advisable to wrap the tank and the water lines with insulation to minimize heat loss. Most new tank-style water heaters are preset to 120° F so be sure to check your temperature setting or call a professional plumber to provide a maintenance check.

Just like the increase in technology for refrigerators there are a number of increasingly efficient water heater models in the marketplace. The Tankless water heater has gained in popularity due to the continuous supply of heated water, elimination of the storage tank and minimum space requirements. The water is only heated when the demand occurs as opposed to storing and heating water throughout the day like conventional tank-style heaters. When choosing to purchase a tankless model a certified electrician should be consulted for the installation and to determine if the electricity capacity is sufficient for the minimum dedicated circuit.

Figure 84. Various Tankless Water Heater models

In addition to increased technologies of water heating equipment one of the most energy efficient methods using standard tank-style units is through Solar Domestic Hot Water Systems. This involves collecting free energy provided by the sun through roof-mounted collectors and a closed loop of antifreeze fluid that transfer the suns energy to the stored water. A backup heater is required due to cloudy overcast periods of time with little sunlight.

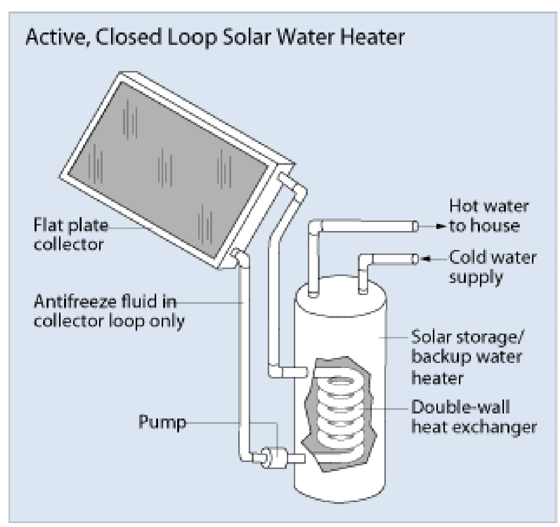

Figure 85. Solar Domestic Hot Water System - DOE

Building Energy Code

As the building science community continues to provide more detailed performance reports of the various components of building construction methods, increased equipment efficiencies, ventilation and moisture control, and thermal conditioning the need for a consistent and progressive building energy code is beneficial as well to ensure that homeowners receive a home that meets a minimum performance and comfort expectation level regardless of where they might live.

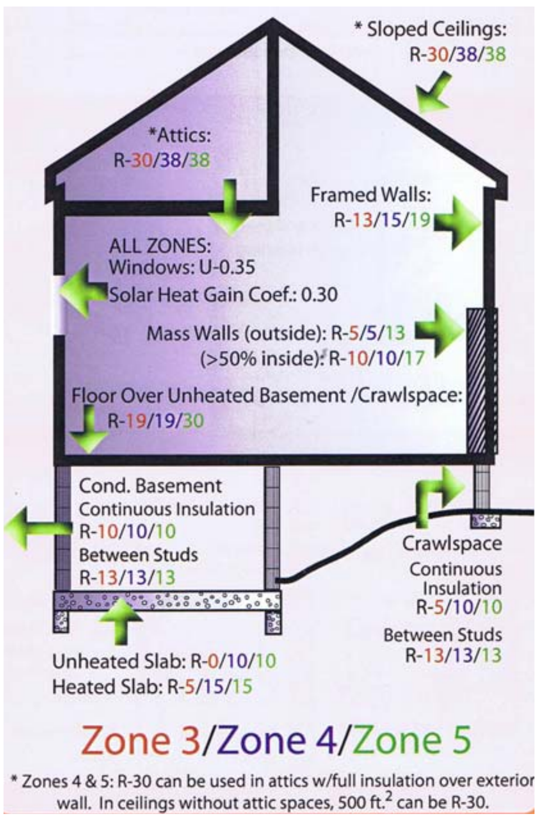

Figure 86. Energy Code Compliance Guide - NC Residential Energy Code 2012 (Appalachian State University Department of Technology and Environmental Design, State Energy Office, NC Department of Commerce)

A building energy code baseline is important and beneficial not only for saving on energy resource use but also in the progressive development of the marketplace and service providers to meet newer standards at an affordable price for homeowners. Homeowners have become much more educated about environmentally issues related to their daily lives and are now requiring certain performance levels out of their homes and equipment.

Key 2012 NC Residential Energy Code Upgrades:

- Increased thermal envelope requirements: R42 ceiling, R18 walls
- Fenestration: maximum U-factor of 0.32 and maximum SHGC of 0.27
- Detailed thermal envelope sealing requirements or blower door testing of the thermal envelope
- HVAC duct system leakage testing

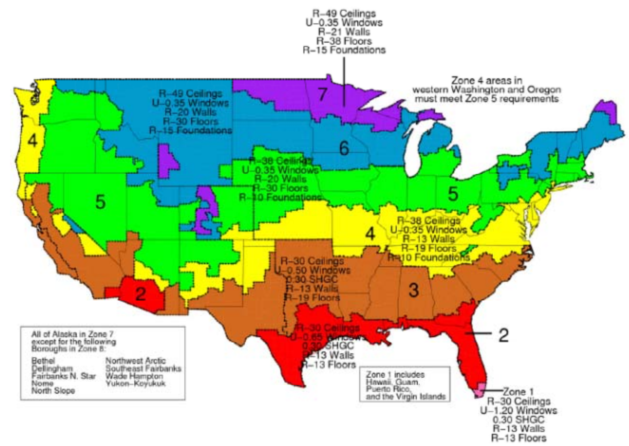

Figure 87. Variations in State Prescriptive Energy Codes based on climate characteristics

> *"He shall set the joints against each other, fitting, and before inserting the dowels he shall show the architect all the stones to be fitting, and shall set them true and sound and dowel them with iron dowels, two dowels to each stone…"*
>
> *Socrates in 341 BC*

Home Performance Metrics and Labeling

A means to communicate to the homeowner public how a certain home performs from an energy standpoint is missing and needed, especially when they are deciding upon the purchase of a home. We have means to better understand how a certain new car may perform with regard to fuel consumption through the Miles Per Gallon (MPG) labeling on new cars. We also have means to understand how much electricity a particular new dishwasher or refrigerator may consume over time through the Energy Guide labeling. Similar information is not widely spread throughout the country for the detached single-family home market and by including the rated performance of a home in the home selection criteria opportunities to increase comfort and energy efficiencies will likely follow. The homeowner will also have greater insight into the home they are considering making an offer on.

Home Energy Rating System (HERS) Index

According to the Home Energy Rating System Index it is the industry standard by which home energy efficiency is measured. It is also the nationally recognized system for inspecting and calculating home energy performance. A certified home energy rater assesses the home assigning it a relative performance score. The US Department of Energy has determined that a typical home for resale scores 130 on the HERS index while a new home is awarded a score of 100. A home with a score of 70 is 30% more efficient than a standard new home. A home with a score of 130 is 30% less efficient than a standard new home.

Area: .			
Style: Craftsman , Traditional		County:	Alachua
Beds:	3	Subdivision:	Belmont
Full Baths:	2	New Constr.:	Yes
Half Baths:	1	Condition:	(NEW)New Construction
HERS Rating (Year Tested):	48 (2011)		
Split BR Plan:	Yes	Sect-Twp-Rng:	27-9-18
Year Built:	2010	Assoc. Fee:	Yes
Total Ht/Cool SF:	2,250	Assoc. Fee $:	92
Total SF Under Roof:	3,006	Assoc. Fee Pd:	Monthly
SqFt Source:	SF from Plans/Appraisal	Parcel Size:	.20 Acres
Parcel Size-Range:	Up to .33	Bank Owned:	No
Apx Lot Dim.:	60x110	Short Sale:	No

Figure 88. MLS listing with HERS index score

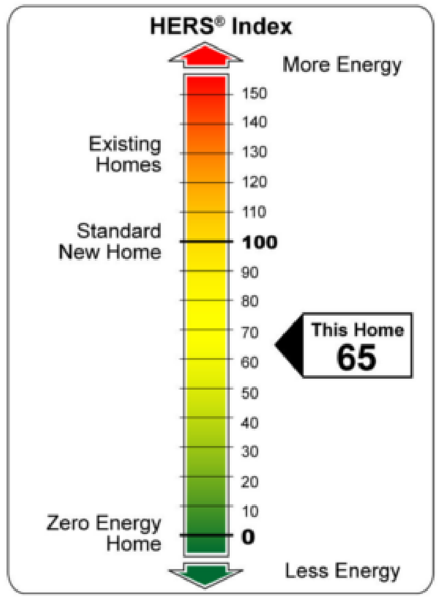

Figure 89. HERS Index Score Label

Municipalities throughout the country have adopted a HERS index listing on home resale Multiple Listing Services (MLS) documents which give a homeowner a better understanding of the particular performance of the home and adds another criteria that they can review during their purchase selection process. Currently, the HERS index score is not included in North Carolina or South Carolina MLS listings, although the MLS template does provide a space for the score, it is just left blank.

Per Steve Baden, RESNET Executive Director, the following states have incorporated HERS Index Scores into MLS:

> Colorado, Florida, Illinois, Maine, Nebraska, New Hampshire, Oklahoma, Texas, Vermont, Virginia, and Wisconsin

The following states have incorporated HERS Index Scores as a Compliance Option to Building Energy Codes:

> Arkansas, Colorado, Idaho, Kansas, Massachusetts, New Mexico, and New York

Energy Star Home Energy Yardstick

Another option for providing energy performance information on homes comes from the EPA Energy Star Home Energy Yardstick web-based tool. This tool accounts for the number of occupants of the home as well as the type of equipment and historical utility data of the home.

Figure 90. Example graphic report from Home Energy Yardstick

Consideration should always be given based on previous energy usage of a house as compared to the projected future use. Not all home owners operate and maintain their homes in the same manner, even if identically built homes of the same age, size and construction standards, are occupied at the same time and location. This labeling goal is intended to give people a base understanding of how a particular home building has performed in the past and can be a good indicator of how it may perform into the future.

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Appendix A
Home Energy Checklist

A practical guide to reducing energy consumption, increasing comfort and reducing utility costs may be achieved by implementing and following a routine checklist of activities performed by homeowners. This checklist is based on four different timeframes that promote for immediate activities for the current day as well as long term goals over a year's period.

The following checklist is provided by the US Department of Energy, Office of Energy Efficiency & Renewable Energy

http://energy.gov/eere/femp/home-energy-checklist

Today

☐	Turn down the temperature of your water heater to the warm setting (120°F). You'll save energy and avoid scalding your hands.
☐	Check if your water heater has an **insulating blanket**. An insulating blanket will pay for itself in one year or less!
☐	Heating can account for almost half of the average family's winter energy bill. Make sure your furnace or heat pump receives professional maintenance each year. And look for the **ENERGY STAR®** label when replacing your system.
☐	Review additional **strategies to reduce your water heating bills**. Water heating can account for 14%-25% of the energy consumed in your home.
☐	Survey your incandescent lights for opportunities to replace them with **compact fluorescent lights (CFLs)** or light-emitting diodes (LEDs). CFLs can save three-quarters of the electricity used by incandescents. The best targets are 60-100 W bulbs used several hours a day.
☐	**Turn off the lights** in unoccupied rooms or consider installing timers, photo cells, or occupancy sensors to reduce the amount of time your lights are on.
☐	**Turn off your computer monitor** when not in use for more than 20 minutes, and turn off both the CPU and monitor if you're not going to use your computer for more than 2 hours.
☐	**Unplug equipment** that drains energy when not in use (i.e. cell phone chargers, fans, coffeemakers, desktop printers, radios, etc.).
☐	Install a **programmable thermostat** that can be adjusted to temperatures according to your schedule. And look for the ENERGY STAR® label when replacing your system.
☐	During winter, open curtains on your south-facing windows during the day to allow sunlight to naturally heat your home, and close them at night to reduce the chill you may feel from cold windows.
☐	**Clean or replace filters** in your furnace, air conditioner, and heat pump.
☐	**ENERGY STAR labeled products** can cut your energy bills by up to 30%. Find retailers near you at **http://www.energystar.gov/**.

This Week

☐	Visit the hardware store. Buy a water-heater blanket, **low-flow showerheads, faucet aerators**, and CFLs, as needed. If you can't find CFLs locally, check out **ENERGYguide** or **Energy Federation Incorporated**.
☐	**Rope caulk or add film** to leaky windows.
☐	Assess your heating and cooling systems. Determine if replacements are justified, or whether you should retrofit them to work more efficiently to provide the same comfort (or better) for less energy.

This Month

☐	**Collect your utility bills**. Separate electricity and fuel bills. Target the largest energy consumer or the largest bill for energy conservation measures.
☐	**Insulate your hot water pipes** to prevent heat loss.
☐	**Insulate heating ducts in unheated areas**, such as attics and crawlspaces. Keeping ducts in good repair can prevent heat loss of up to 60% at the registers.
☐	**Seal up the largest air leaks** in your house—the ones that whistle on windy days, or feel drafty. The worst culprits are usually not windows and doors, but utility cut-throughs for pipes ("plumbing penetrations"), gaps around chimneys and recessed lights in insulated ceilings, and unfinished spaces behind cupboards and closets. Better yet, hire an energy auditor with a blower door to point out the worst cracks. All the little, invisible cracks and holes may add up to as much as an open window or door without you ever knowing it!

☐	Install a **programmable thermostat** to set your thermostat back automatically at night.
☐	Schedule an **energy audit** (ask your utility company or state energy office) for more expert advice on your home as a whole. Learn more about **home energy audits**.

This Year

☐	**Insulate**. If your walls aren't insulated have an insulation contractor blow cellulose into the walls. Bring your attic insulation level up to snuff.
☐	**Replace aging, inefficient appliances**. Even if the appliance has a few useful years left, replacing it with a top-efficiency model is generally a good investment. Especially check the age and condition of your refrigerator.
☐	**Upgrade leaky windows**. It may be time to replace them with energy-efficient models or to boost their efficiency with weatherstripping and storm windows. The typical home loses more than 25% of its heat through windows.
☐	**Upgrade your computer and monitor**. Consider replacing your desktop computer with a notebook computer and docking station, and your cathode ray tube (CRT) monitor with a liquid crystal display (LCD) or LED monitor. (See **Estimating Appliance and Home Electronic Energy Use**.)
☐	Reduce your air conditioning costs by **planting shade trees and shrubs** around your house-especially on the west side.
☐	Know that you are making a difference!

These tips were taken from the **Consumer Guide to Home Energy Savings**. For additional information on home energy conservation/efficiency measures, visit the **Consumer Energy Center** and the **Home Energy Saver Answer Desk**.

A DO-IT-YOURSELF GUIDE TO SEALING AND INSULATING WITH ENERGY STAR®

SEALING AIR LEAKS AND ADDING ATTIC INSULATION

ENERGY STAR

Seal and Insulate with ENERGY STAR

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Sealing and Insulating your home is one of the most cost-effective ways to make a home more comfortable and energy efficient—and you can do it yourself.

Use This Guide To:

1. Learn how to find and seal hidden attic and basement air leaks
2. Determine if your attic insulation is adequate, and learn how to add more
3. Make sure your improvements are done safely
4. Reduce energy bills and help protect the environment

CONTENTS

When you see products or services with the ENERGY STAR® label, you know they meet strict energy efficiency guidelines set by the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE). Since using less energy reduces greenhouse gas emissions and improves air quality, choosing ENERGY STAR is one way you can do your part to protect our planet for future generations.

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The U.S. EPA wishes to thank The Family Handyman Magazine for their contribution of photographs and content for this guide.

LOCATING AIR LEAKS

More than any other time of year, you notice your home's air leaks in the winter. Most people call these air leaks "drafts." You may feel these drafts around windows and doors and think these leaks are your major source of wasted energy. In most homes, however, the most significant air leaks are hidden in the attic and basement. These are the leaks that significantly raise your energy bill and make your house uncomfortable. In cold weather, warm air rises in your house, just like it does in a chimney. This air, which you have paid to heat, is just wasted as it rises up into your attic and sucks cold air in all around your home—around windows, doors, and through holes into the basement. The illustrations on Page 1.3 and 3.1 show warm air leaving (red arrows) the house through the attic and cold air being pulled into the house (blue arrows). Locating these leaks can be difficult because they are often hidden under your insulation. This guide will help you find these leaks and seal them with appropriate materials.

Even if you have enough insulation in your attic, sealing attic air leaks will enhance the performance of your insulation and make for a much more comfortable home.

If you are not familiar with some of the terms in this guide, check our glossary inside the back cover.

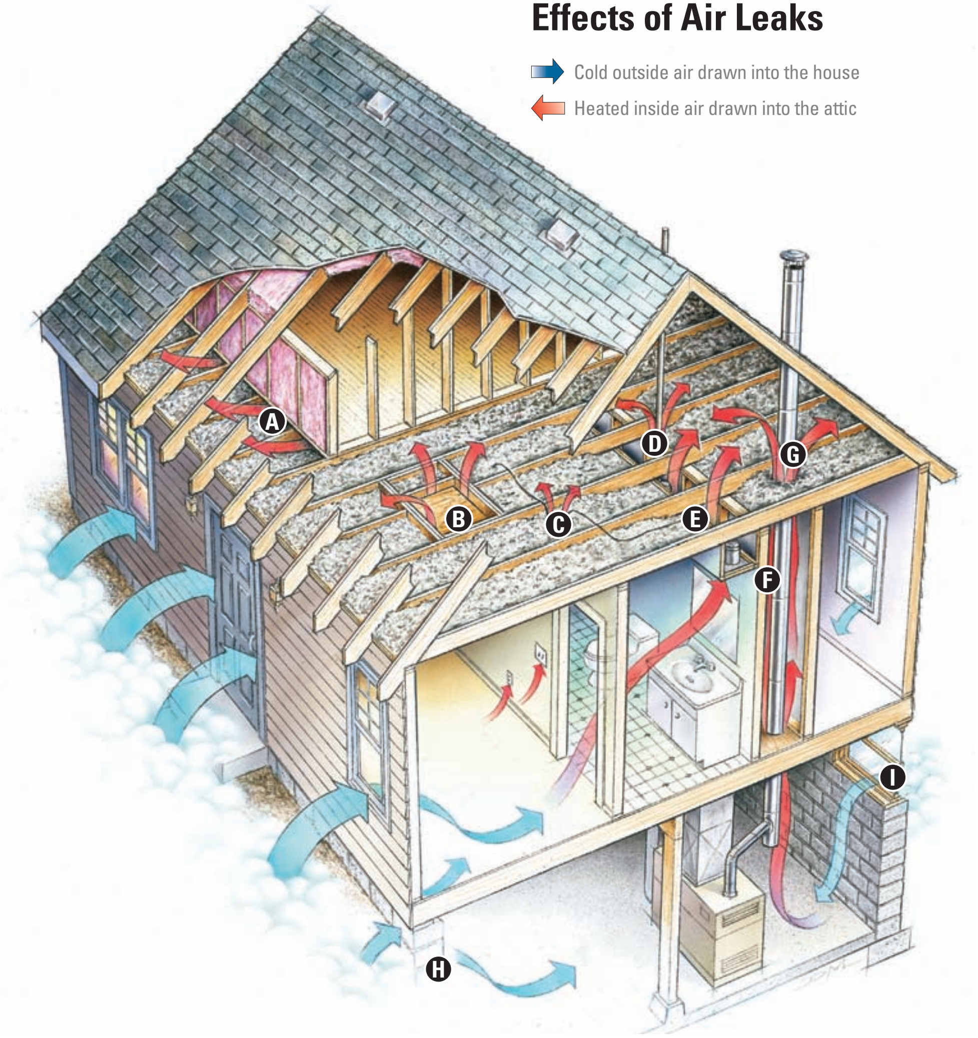
Common Household Air Leaks

- **A** Behind Kneewalls
- **B** Attic Hatch
- **C** Wiring Holes
- **D** Plumbing Vent
- **E** Open Soffit (the box that hides recessed lights)
- **F** Recessed Light
- **G** Furnace Flue or Duct Chaseways (the hollow box or wall feature that hides ducts)
- **H** Basement Rim Joists (where the foundation meets the wood framing)
- **I** Windows and Doors

Effects of Air Leaks

Cold outside air drawn into the house

Heated inside air drawn into the attic



You May Need a Contractor to Correct These Problems:

- Wet or damp insulation indicating a leaky roof
- Moldy or rotted attic rafters or floor joists indicating moisture problems
- Kitchen, bathroom, and clothes dryer vents that exhaust moist air directly into the attic space instead of outdoors
- A history of ice dams in the winter (an indication of serious air leaks)
- Little or no attic ventilation (see Page 4.2 – A Note About Attic Ventilation)
- Knob and tube wiring (pre-1930), which can be a fire hazard when in contact with insulation
- If you have many unsealed and uninsulated recessed "can" lights, special care must be taken when insulating around these fixtures (See Page 2.2)

Attic air sealing and adding insulation are do-it-yourself projects if your attic is accessible and not too difficult to move around in. The projects recommended in this guide can usually be completed in a day or two and will provide benefits for years to come. However, if upon inspection of your attic you find any of the conditions listed to the left, we recommend you consider hiring a contractor to correct these problems before proceeding.

For tips on hiring the right contractor, visit **www.energystar.gov/homeimprovement**.

Get Your Bearings from Below

A good way to start home sealing is to make a quick sketch of your home's floor plan. This sketch will serve as a reference point once you get into the attic and will help you locate areas of leakage. In your sketch, make note of dropped soffits over kitchen cabinets or bath vanities, slanted ceilings over stairways, where walls (interior and exterior) meet the ceiling, and any other dropped-ceiling areas. These areas may have open stud cavities leading directly into the attic and can be huge sources of air leaks (see photos 1-3 on Pages 1.6 and 1.7).

Tips For Working in the Attic

Have a Plan in Place

The key to any successful home improvement project is adequate planning. Gather all your tools and supplies before you begin to minimize trips in and out of the attic. Be sure that the work area is well-lit by using a drop light, and keep a flashlight handy.

Prepare to Get Dirty

The entire process of sealing your attic will be made easier if you take the time and effort to wear the right gear. Wear knee pads to help prevent pain associated with crawling on attic joists. Additionally, a lightweight disposable coverall, gloves, and hat can keep itchy and irritating insulation off your skin.

Above All – Be Safe

Take precautions to avoid a dangerous working environment in the attic. During hot weather start working early, as attics heat up as the day moves on. Drink plenty of water and use an OSHA-approved particulate respirator or double-strap dust mask to prevent inhalation of hazardous substances. Also remember to watch your step. Walk on joists or truss chords, not exposed ceiling drywall or insulation. In addition, watch out for sharp nails sticking through the roof deck!

Materials Checklist for Sealing Attic Air Leaks

- Batt or roll of unfaced fiberglass insulation and large garbage bags (for stuffing open stud cavities behind kneewalls and in dropped soffits)
- Roll of reflective foil insulation or other blocking material such as drywall or pieces of rigid foam insulation to cover soffits, open walls, and larger holes
- Silicone or acrylic latex caulk & caulk gun for sealing small holes (1/4 inch or less)
- Several cans of expanding spray foam insulation for filling larger gaps (1/4 inch to 3 inches)
- Special high-temperature (heat-resistant) caulk to seal around flues and chimneys
- Roll of 14-inch wide aluminum flashing to keep insulation away from the flue pipe
- Retractable utility knife and sheet metal scissors
- Tape measure and staple gun (or hammer and nails) to hold covering materials in place
- Safety glasses, gloves, and dust mask (for insulation work as well)
- Flashlight or portable safety light
- Boards to walk on, if needed
- Large bucket to haul materials

SEALING ATTIC AIR LEAKS

Plug the Big Holes First

Don't worry about finding and sealing all the little holes in your attic; your biggest savings will come from plugging the large ones. Once in the attic, refer to your sketch to locate the areas where leakage is likely to be greatest: where walls (inner and outer) meet the attic floor, dropped soffits (dropped-ceiling areas), and behind or under attic kneewalls. Look for dirty insulation—this indicates that air is moving through it. Dropped soffits may be filled or covered with insulation and hard to see. Push back the insulation and scoop it out of the soffits. You will place this insulation back over the soffit once the stud cavities have been plugged and the soffits covered (photos 1-3) (If you have recessed "can" lights in your open soffits, please read about them on Page 2.2 before proceeding).

1. CREATE STUFFED BAGS

Cut a 16 inch long piece from a batt of unfaced fiberglass insulation and fold it into the bottom of a 13-gallon plastic garbage bag.

2. PLUG OPEN STUD CAVITIES

Fold the bag and stuff it into the open stud cavity. Add more insulation to the bag if it doesn't fit tightly. Plug all open stud spaces, then cover the soffit (photo 3, Page 1.7).

3. COVER DROPPED SOFFITS

After removing insulation from a dropped soffit, cut a length of reflective foil or other blocking material (rigid foam board works well) a few inches longer than the opening to be covered. Apply a bead of caulk or adhesive around the opening. Seal the foil to the frame with the caulk/adhesive and staple or nail it in place, if needed.

4. SEAL BEHIND KNEEWALLS

Cut a 24 inch long piece from a batt of fiberglass insulation and place it at the bottom of a 13-gallon plastic garbage bag. Fold the bag over and stuff it into the open joist spaces under the wall (a piece of rigid foam board sealed with spray foam also works well for covering open joist cavities). Again, cover with insulation when you're done.

If You Have a Finished Attic, Seal Behind the Kneewalls

Finished rooms built into attics often have open cavities in the floor framing under the side-walls or kneewalls. Even though insulation may be piled against or stuffed into these spaces, they can still leak air. Again, look for signs of dirty insulation to indicate air is moving through. You need to plug these cavities in order to stop air from traveling under the floor of the finished space (photo 4).

Caution: Some attics have vermiculite insulation, which may contain asbestos, a health hazard. Vermiculite is a lightweight, pea-size, flaky gray mineral. Don't disturb vermiculite insulation unless you've had it tested by an approved lab to be sure it doesn't contain asbestos. Contact your local health department for the name of an approved lab.

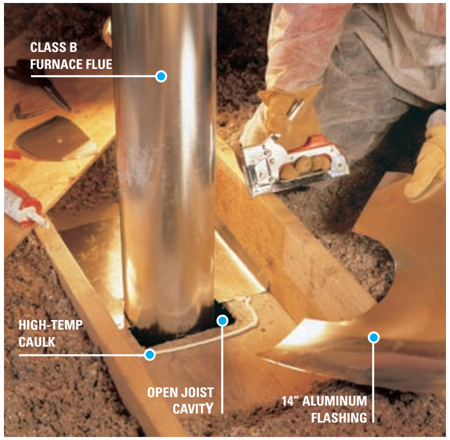
SEALING ATTIC AIR LEAKS

Furnace Flues Require Special Sealing Techniques

The opening around a furnace or water heater flue or chimney can be a major source of warm air moving in the attic. Because the pipe gets hot, building codes usually require 1 inch of clearance from metal flues (2 inches from masonry chimneys) to any combustible material, including insulation. Photos 5 and 6 show how to seal this gap with lightweight aluminum flashing and special high-temperature (heat-resistant) caulk. Before you push the insulation back into place, build a metal dam (photo 7) to keep it away from the pipe. Use the same technique for masonry chimneys.

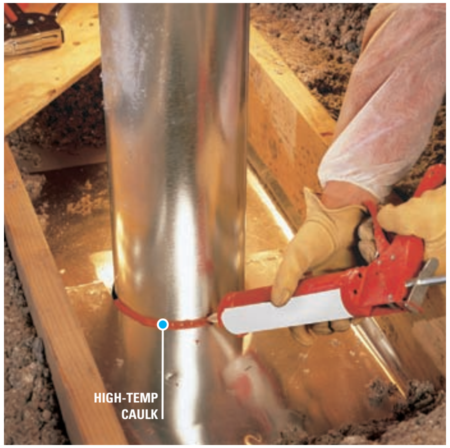
Caution: Furnace flues (the pipe that removes your furnace exhaust) can be very hot.

5. CUT ALUMINUM FLASHING



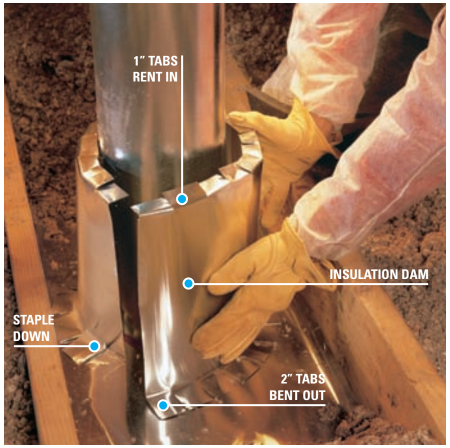
Cut aluminum flashing to fit around the flue. For round flues, cut half circles out of two pieces so they overlap about 3 inches in the middle. Press the flashing metal into a bead of high-temperature caulk and staple or nail it into place. If there's no wood, staple or nail it directly to the drywall, but be sure not to staple or nail through the drywall.

6. SEAL WITH SILICONE CAULK



Seal the gap between the flue and metal flashing with special high-temperature caulk. Don't use spray foam.

7. FORM AN INSULATION DAM



Form an insulation dam to prevent insulation from contacting the flue pipe. Cut enough aluminum from the coil to wrap around the flue plus 6 inches. Cut slots 1 inch deep and a few inches apart along the top and bend the tabs in. Cut slots about 2 inches deep along the bottom and bend out the tabs. Wrap the dam around the flue and secure the bottom by stapling through the tabs. Now put insulation back right up against the dam.

Identifying Attic Pipes

FLUES/VENTS/PIPES:	MADE OUT OF:	SEAL AROUND WITH:
Furnace/Water Heater	Galanized Metal	Aluminum flashing and high-temperature silicone caulk
Chimney	Masonry/Metal	Aluminum flashing and high-temperature silicone caulk
Plumbing	Cast Iron or PVC	Expanding foam or caulk, depending on size of gap

SEALING ATTIC AIR LEAKS

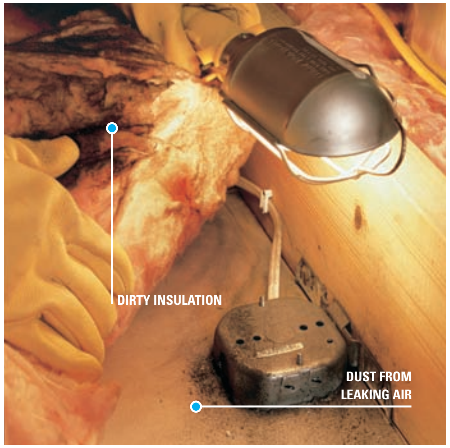
Foam or Caulk Small Gaps in Your Attic

Even though most of the gaps spilling warm air into your attic are buried under insulation, you might be able to find evidence of these gaps. Look for areas where the insulation is darkened (see photo 8). This is the result of filtering dusty air from the house. In cold weather, you may also see frosty areas in the insulation caused by warm, moist air condensing and then freezing as it hits the cold attic air. In warmer weather, you'll find water staining in these same areas. Although the insulation is dirty, it is still okay to use. There's no need to remove and replace. After sealing the areas, just push the insulation back into place. If you have blown insulation, a small rake can be helpful to level it back into place.

Seal Small Gaps

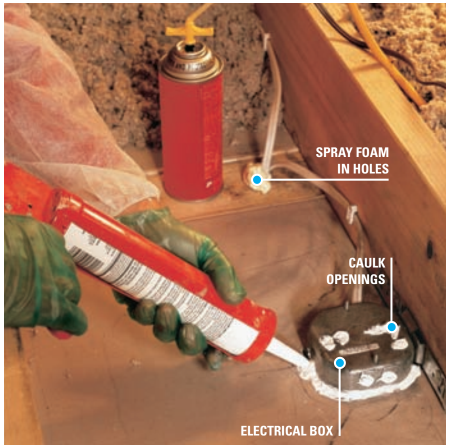
Use expanding foam or caulk to seal the openings around plumbing vent pipes and electrical wires (see photos 9 and 10). Be sure to wear gloves and be careful not to get expanding foam on your clothes, as the foam is very sticky and nearly impossible to remove once it sets. When the foam or caulk is dry, cover the area again with insulation.

8. FIND ATTIC BYPASSES



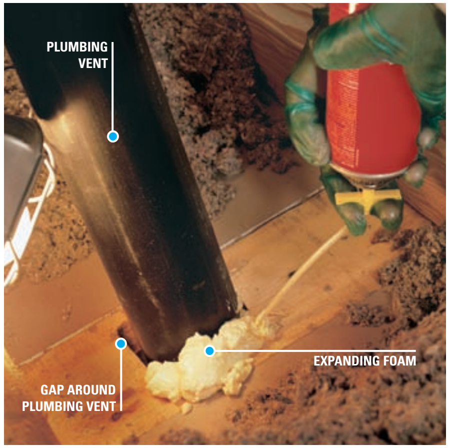
Check for gaps in your attic that facilitate air movement by checking for dirty insulation. Seal the gaps with caulk or expanding foam. When complete and dry, push the insulation back into place.

9. FILL HOLES WITH CAULK



Fill wiring and plumbing holes with expanding foam. Caulk around electrical junction boxes, and fill holes in box with caulk.

10. STUFF GAPS WITH INSULATION



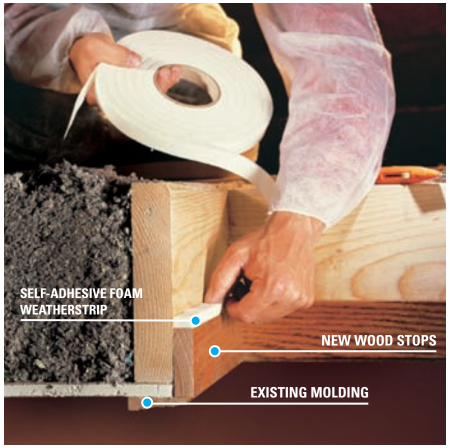
If the space around your plumbing pipe is wider than 3 inches, you may need to stuff some fiberglass insulation into the space to serve as a backer for the expanding foam. Once the fiberglass insulation is in place, follow the directions on the can to foam the space around the pipe.

SEALING ATTIC AIR LEAKS

Complete the Job by Sealing the Attic Hatch or Door

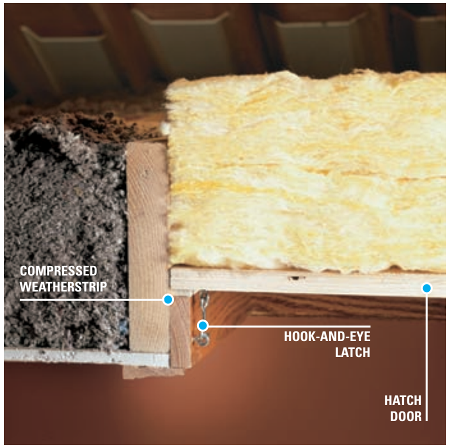
Finish up by sealing the access hatch with self-sticking weather stripping (photos 11 and 12). If your hatch rests directly on the moldings, add 2-1/2 inch wide stops around the opening. The stops provide a wider surface for attaching the weatherstrip and a space to mount hook-and-eye fasteners. Position the screw eyes so the weatherstrip is slightly compressed when the hooks are latched. Cut a piece of fiberglass or rigid foam board insulation the same size as the attic hatch and nail or glue it to the back of the hatch. If you have pull-down attic stairs or an attic door, these should be sealed in a similar manner: weatherstrip the edges and put a piece of rigid foam board insulation on the back of the door. Treat the attic door like a door to the outside. Pre-made insulated attic stair covers are also available from local home improvement centers or on the Web.

11. WEATHERSTRIP THE DOOR



Weatherstrip the attic access hatch or door. Cut 1x3 boards to fit the perimeter of the opening and nail them on with 6d finish nails. Apply self-adhesive foam weatherstrip tape to the top edge of the stop.

12. ATTACH FASTENERS



Attach hook-and-eye fasteners to the attic door and stops. Position the eyes so that the weatherstrip is compressed when you latch the hooks.

ADDITIONAL SOURCES OF AIR LEAKS

If Your Heating and Cooling Ducts Are in Your Attic, Seal Them While in the Attic

Leaky and poorly-insulated ducts (especially in attics) severely compromise the performance of your heating and cooling equipment. Sealing and insulating your ducts can increase the efficiency of your heating and cooling system by 20% and greatly increase air flow.

- Check the duct connections for leaks by turning on your heating and cooling system fan and feeling for leaks—seal the joints with mastic or foil tape (household duct tape should not be used).
- Pay special attention to all the duct penetrations going through the attic floor. Seal these with foam.
- Ducts should also be insulated—if your ducts are uninsulated or poorly insulated (i.e., you see gaps or torn insulation), seal them first, then add insulation to keep the air in your ducts at your desired temperature as it moves through the system. Use duct insulation material rated at least R-6.

Materials Checklist for Attic Duct Sealing

- Duct sealant (mastic) or metal-backed (foil) tape
- Duct insulation material rated at least R-6
- Zip ties to hold duct insulation in place
- Gloves, safety glasses, mask, flashlight

NOTE: Duct sealant, also known as duct mastic, is a paste which is more durable than foil duct tape. It is available at home improvement centers. Traditional grey duct tape fails quickly and should not be used.

Caution: Check for Carbon Monoxide to keep your house safe. After making energy improvements that result in a tighter house, there can be an increased opportunity for CO to build up if your gas-burning appliances are not venting properly. Have your heating and cooling technician check your combustion appliances (gas- or oil-fired furnace, water heater, and dryer) for proper venting. For additional information on Indoor Air Quality (IAQ) issues related to homes such as combustion safety, indoor air contaminants, and proper ventilation, visit www.epa.gov/iaq/homes/hip-front.html.

ADDITIONAL SOURCES OF AIR LEAKS

Recessed "Can" Lights: Big Source of Air Leaks, But No Easy Solution

Recessed "can" lights (also called high-hats or recessed downlights) look great, but when they protrude into your attic space, they can make your home less energy-efficient. These recessed lights in a one-story house or in the ceiling of a second-story create open holes into your attic that allow unwanted heat flow between conditioned and unconditioned spaces. In the summer, hot attic air can make the rooms warmer, and in the winter can lights draw warm air up into your attic. Both the warm air leakage and the heat from the lights can cause problems. In cold climates, the heat melts snow on the roof and forms ice dams (water re-freezes at the roof edge). This is more likely to happen if the "can" light is close to the roof deck. Recessed "can" lights in bathrooms also cause problems when warm, moist air leaks into the attic and causes moisture damage. Here are some suggestions for improving the recessed can lights in your attic:

- **Call a Professional to Properly Seal**
  Recessed lights can be sealed, but it is difficult and can create a hazard if not done properly with non-combustible materials. Since any old-style lights need adequate air space around them to vent the heat they create, it's best to consult with a professional before sealing them. Also, see "Caution" below. Alternatively, recessed lights can be replaced with ICAT (Insulated Ceiling Air-Tight) rated lights, which insulation can touch and are sealed to reduce air leaks.

- **When Replacing or Adding, Buy ENERGY STAR with ICAT**
  Look for ENERGY STAR qualified recessed fixtures that reduce energy use as much as 75%. However, it's important to check that any fixture selected meets your light output expectations since fixtures come with widely varying wattage bulbs and optics. Also, make sure fixtures have an ICAT rating to minimize heat loss.

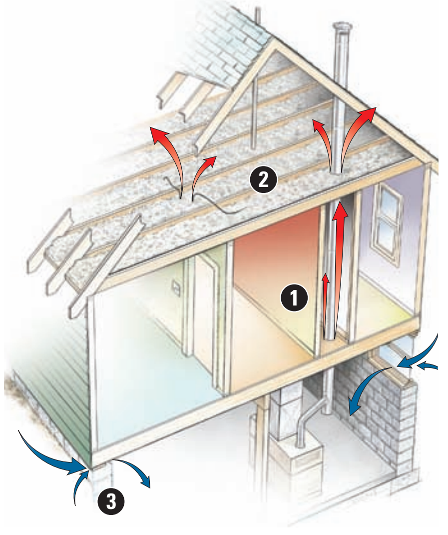
- **Switch to More Efficient Bulbs**
  When keeping existing recessed lights, you can still reduce lighting energy use as much as 75% by installing ENERGY STAR qualified compact fluorescent light (CFL) bulbs. This includes CFL bulbs specifically designed for recessed lights with built-in reflectors matching the appearance of traditional incandescent reflector bulbs. As with new fixtures, it is important to make sure any CFL bulb selected meets your light output expectations. Also, check the packaging of the CFL to ensure that it may be used in an enclosed fixture. However, switching to CFL bulbs will not solve the air leakage problem.

Caution: Keep all insulation 3 inches from "can" lights, except those rated IC (insulation contact). You can use a piece of circular metal flashing or wire mesh around the light as a dam to keep the insulation away from the light (see photo 2, Page 4.3).

SEALING BASEMENT AIR LEAKS

Stopping the Chimney Effect

Outside air drawn in through basement leaks is exacerbated by the chimney effect created by leaks in the attic. As hot air generated by the furnace rises up through the house ❶ and into the attic through leaks ❷, cold outside air gets drawn in through basement leaks to replace the displaced air ❸. This makes a home feel drafty and contributes to higher energy bills. After sealing attic air leaks, complete the job by sealing basement leaks, to stop the chimney effect.



Locating Basement Air Leaks

A common area of air leakage in the basement is along the top of the basement wall where cement or block comes in contact with the wood frame. These leaks can easily be fixed in portions of the basement that are unfinished. Since the top of the wall is above ground, outside air can be drawn in through cracks and gaps where the house framing sits on top of the foundation. This perimeter framing is called the rim (or band) joist. In the basement, the above floor joists end at the rim joist creating multiple cavities along the length of the wall, and many opportunities for leakage (see illustration on Page 3.2).

SEALING BASEMENT AIR LEAKS

Seal All Gaps and Cracks around Rim Joists

Though you may not be able to see cracks in the rim joist cavities, it is best to seal up the top and bottom of the inside of the cavity. Also, rim joist air sealing is especially important at bump out areas such as bay windows that hang off the foundation. These areas provide greater opportunities for air leakage and heat loss. Caulk is best for sealing gaps or cracks that are 1/4 inch or less. Use spray foam to fill gaps from 1/4 inch to about 3 inches. We also recommend you seal penetrations that go through the basement ceiling to the floor above. Generally, these are holes for wires, water supply pipes, water drain pipes, the plumbing vent stack (for venting sewer gases), and the furnace flue (for venting furnace exhaust).

Materials Checklist for Basement Sealing

- Silicone or acrylic latex caulk and caulk gun
- Expanding spray foam

Caution: When sealing the furnace flue (which will be encased in a metal sleeve) use high-temperature caulk. Run a bead of high-temperature caulk around the pipe sleeve and around the metal frame.

Areas to Foam or Caulk

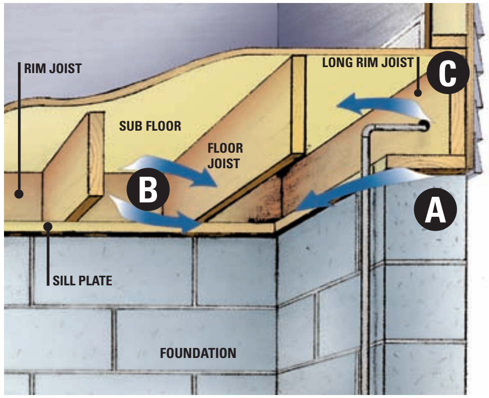


ILLUSTRATION BY DALE HOFFMEYER

A Along the gap between the sill plate and the foundation

B At the bottom and top of the rim joist on each end of the house

C All electrical, water, or gas penetrations and any venting ducts that pass to the outside

What About Insulating the Rim Joist?

After air sealing the rim joist area it is relatively easy to insulate each cavity with rigid foam insulation or fiberglass batts. If using batts, just cut the insulation to fit and place against the rim joist without compression, gaps, or voids. If using rigid, foam into place. This could also be done in conjunction with finishing the basement, when you would insulate the basement walls floor-to-ceiling. Attic and basement air sealing will go a long way to improve your comfort because your house will no longer act like an open chimney.

ADDING ATTIC INSULATION

Now that you've air-sealed your attic and basement, check your attic insulation levels and add more if necessary. The attic is the easiest place to add insulation to improve your comfort and the energy efficiency of your home.

Do I Have Enough?

No matter what kind of insulation you currently have in your attic, one quick way to determine if you need more is to look across the span of your attic. If your insulation is just level with or below your floor joists (i.e., you can easily see your joists), you should add more. If you cannot see any of the floor joists because the insulation is well above them, you probably have enough and adding more may not be cost-effective. It is important that the insulation be evenly distributed with no low spots; sometimes there is enough insulation in the middle of the attic and very little along the eaves. To see how to add insulation out to the eaves, see Installing Rafter Vents (on Page 4.4). If your attic insulation covers your joists and is distributed evenly, you probably have enough.

How Much Should I Add?

Insulation levels are specified by R-Value. R-Value is a measure of insulation's ability to resist heat flow. The higher the R-Value, the better the thermal performance of the insulation. The recommended level for most attics is to insulate to R-38 or about 10 to 14 inches, depending on insulation type.

ADDING ATTIC INSULATION

A Note about Natural Attic Ventilation

At first it may seem odd to add insulation for warmth and then purposely allow cold air to enter the attic through vents, but this combination is the key to a durable and energy-efficient home. Here's why: in the winter, allowing a natural flow of outdoor air to ventilate the attic helps keep it cold, which reduces the potential for ice damming (snow that melts off a roof from an attic that is too warm and then re-freezes at the gutters, causing an ice dam that can damage the roof). Proper insulation and air sealing also keeps attics cold in winter by blocking the entry of heat and moist air from below. In the summer, natural air flow in a well-vented attic moves super-heated air out of the attic, protecting roof shingles and removing moisture. The insulation will resist heat transfer into the house. The most common mistake homeowners make when installing insulation is to block the flow of air at the eaves. NEVER COVER ATTIC SOFFIT VENTS WITH INSULATION—use rafter vents and soffit vents to maintain airflow (See Pages 4.4 and 4.5).

A Note about Attic Fans

Attic fans are intended to cool hot attics by drawing in cooler outside air from attic vents (soffit and gable) and pushing hot air to the outside. However, if your attic has blocked soffit vents and is not well-sealed from the rest of the house, attic fans will suck cool conditioned air up out of the house and into the attic. This will use more energy and make your air conditioner work harder, which will increase your summer utility bill. You don't want your unfinished attic cooled by your air conditioner. To prevent this, follow the air sealing and insulation strategies in this guide and make sure the attic is well-ventilated using passive vents and natural air flow.

Use a blowing machine to blow in loose fill insulation.

Photo courtesy of Green Fiber

Add the Right Kind of Insulation

When adding additional insulation, you do not have to use the same type of insulation that currently exists in your attic. You can add loose fill on top of fiberglass batts or blankets, and vice-versa. If you use fiberglass over loose fill, make sure the fiberglass batt has no paper or foil backing; it needs to be "unfaced." If you choose to add loose fill, it may be wise to hire a professional, as the application requires the use of a blowing machine, although some home improvement stores offer rentals of this machine.

Doing the Job

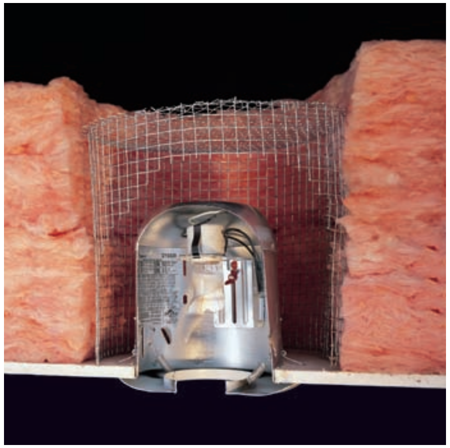
Laying fiberglass rolls is easiest for a DIY job. If you have any type of insulation between the rafters, install the second layer over and perpendicular to the first (again, the second layer of roll insulation should be unfaced– with no vapor retarder). This will help cover the tops of the joists and reduce heat loss or gain through the frame. Also, when laying down additional insulation, work from the perimeter toward the attic opening. Never lay insulation over recessed light fixtures or soffit vents. Keep all insulation at least 3 inches away from "can" lights, unless they are rated IC (Insulated Ceiling). If you are using loose fill insulation, use sheet metal to create barriers around the openings. If using fiberglass, wire mesh can be used to create a barrier.

1. LAY FIBERGLASS ROLLS

Layer fiberglass roll insulation perpendicular to the joists.

Photo courtesy North American Insulation Manufacturers Association

2. CREATE A BARRIER



Use sheet metal or wire mesh to help create a barrier around fixtures or vents.

ADDING ATTIC INSULATION

Installing Rafter Vents

To completely cover your attic floor with insulation out to the eaves you need to install rafter vents (also called insulation baffles). Complete coverage of the attic floor along with sealing air leaks will ensure you get the best performance from your insulation. Rafter vents ensure the soffit vents are clear and there is a channel for outside air to move into the attic at the soffits and out through the gable or ridge vent (see Attic Air Flow graphic on Page 4.5).

To install the rafter vents, staple them directly to the roof decking. Rafter vents come in 4-foot lengths and 14-1/2 and 22-1/2 inch widths for different rafter spacings.

Rafter vents should be placed in your attic ceiling in between the rafters at the point where your attic ceiling meets your attic floor. Once they are in place, you can then place the batts or blankets, or blow insulation, right out to the very edge of the attic floor. Note: Blown insulation may require an additional block to prevent insulation from being blown into the soffit (see Page 4.5). A piece of rigid foam board placed on the outer edge of the top plate works very well for this.

3. PLACE RAFTER VENTS

Place rafter vents in between the rafters where the ceiling meets the floor.

Photo courtesy of Doug Anderson

4. ADD INSULATION

Add insulation around the rafter vent and out to the edge of the attic floor.

Photo courtesy of Doug Anderson

Attic Air Flow

The outside air flows through the soffit, along the rafter vent and out through the gable or ridge vent.

A RAFTER VENT

B SOFFIT VENT

C RIDGE VENT

NOTE: Gable vent not shown in this diagram.

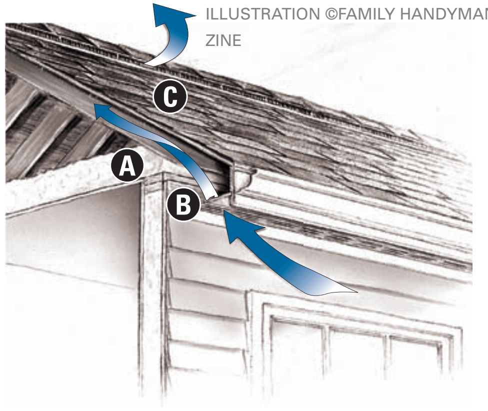


ILLUSTRATION ©FAMILY HANDYMAN MAGAZINE

For additional information on Indoor Air Quality (IAQ) issues related to homes such as combustion safety, indoor air contaminants, and proper ventilation, visit: **http://www.epa.gov/iaq/homes/hip-front.html.**

GLOSSARY

ENERGY STAR – ENERGY STAR is a government-backed program helping businesses and individuals protect the environment through superior energy efficiency. To learn more about the wide variety of energy-efficient ENERGY STAR products and processes visit **http://www.energystar.gov.**

Seal and Insulate with ENERGY STAR – A process recommended by the ENERGY STAR Program for improving the envelope of a home to make it more comfortable and energy-efficient. The process includes sealing air leaks and adding insulation where cost-effective.

Air Duct – A hollow conduit or tube (square or round) that circulates air from a forced-air heating and/or cooling system to a room (supply duct) or returns air back to the main system from a room (return duct).

Air Leak – A hole, crack, or gap where air can leak in or out of a house. Air leaks can make a home feel drafty or uncomfortable and waste energy (See Page 1.3).

Gable Vent – A screened vent installed at or near the peak of a roof gable that allows warm attic air to escape.

Insulation – A material that is designed to slow down the flow of heat in or out of a building structure.

Joist – A beam used to support floors or roofs (See Page 3.2).

Kneewall – A short wall in a room with a sloped ceiling. It is usually formed when the room ceiling follows the roof line of a house (See Page 1.3).

Rafter Vent – A vent leading from the soffit into the attic through the space between the attic rafters. This vent allows air to correctly flow past insulation into the attic space (See Pages 4.4 or 4.5).

Recessed "Can" Light – A metal light fixture (or can) that is in-set into the ceiling. These fixtures can be a big source of air leaks when installed in the upper floor of a home (See Pages 1.6 and 4.3).

Ridge Vent – A screened vent installed along the top ridge of a roof that allows warm attic air to escape (See Page 4.5).

Sill Plate – A wood plank that lays flat on top of a concrete or masonry foundation or wall that supports a floor or ceiling joist (See Page 3.2).

Soffit – The underside of a building overhang, beam, or arch, especially the underside of a stair or roof overhang (See Page 4.5).

Soffit Vent – A screened vent in a house soffit that allows air to flow into the attic or the space below the roof sheathing. This helps keep the attic cool in the summer and allows moisture in the attic to evaporate (See Page 4.5).

For more information
www.energystar.gov
or call **1.888.STAR.YES**
(1.888.782.7937).

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Appendix C - Duct Sealing Data

Regional Duct Sealing Data Compilation

Aeroseal Data - Fresh Air Technologies, Inc. (Compiled by GREENTHINC., PLLC)							8-Nov-14
House No.	Zip Code	CFM Leakage		% reduction	Hole Size (Sq. In.)		HVAC Capacity Improvement %
		Before	After		Before	After	
1	28211	220	2	99	42	0	42
2	28027	175	2	99	33	0	36
3	28117	167	13	92	32	2	18
4	28112	157	15	90	30	3	17
5	28034	143	9	94	27	2	29
6	28112	132	29	78	25	5	23
7	28211	128	8	93	24	2	26
8	28226	119	9	93	23	2	25
9	28226	105	11	90	20	2	21
10	28134	102	4	96	19	1	22
11	28226	98	7	93	19	1	21
12	28205	97	9	91	18	2	20
13	28027	93	7	93	18	1	11
14	28277	91	14	85	17	3	10
15	28270	90	4	95	17	1	20
16	28277	89	16	82	17	3	17
17	28173	83	8	90	16	2	18
18	28207	77	3	96	15	1	18
19	29732	65	3	95	12	1	15
20	28227	65	9	86	12	2	7
21	28227	60	10	84	11	2	12
22	28036	53	8	84	10	2	11
23	28034	49	6	89	9	1	11
24	28112	38	11	70	7	2	3
25	28211	33	4	87	6	1	7
26	28207	32	11	66	6	2	5
27	28075	28	1	95	5	0	6
28	28210	21	3	87	4	1	5
29	28273	10	2	79	2	0	1
Average		90.3	8.2	88.7	17.1	1.6	16.4

Figure 1. 29 Detached Single-Family Home Regional Case Study for Internal Duct Sealing Before-and-After Performance

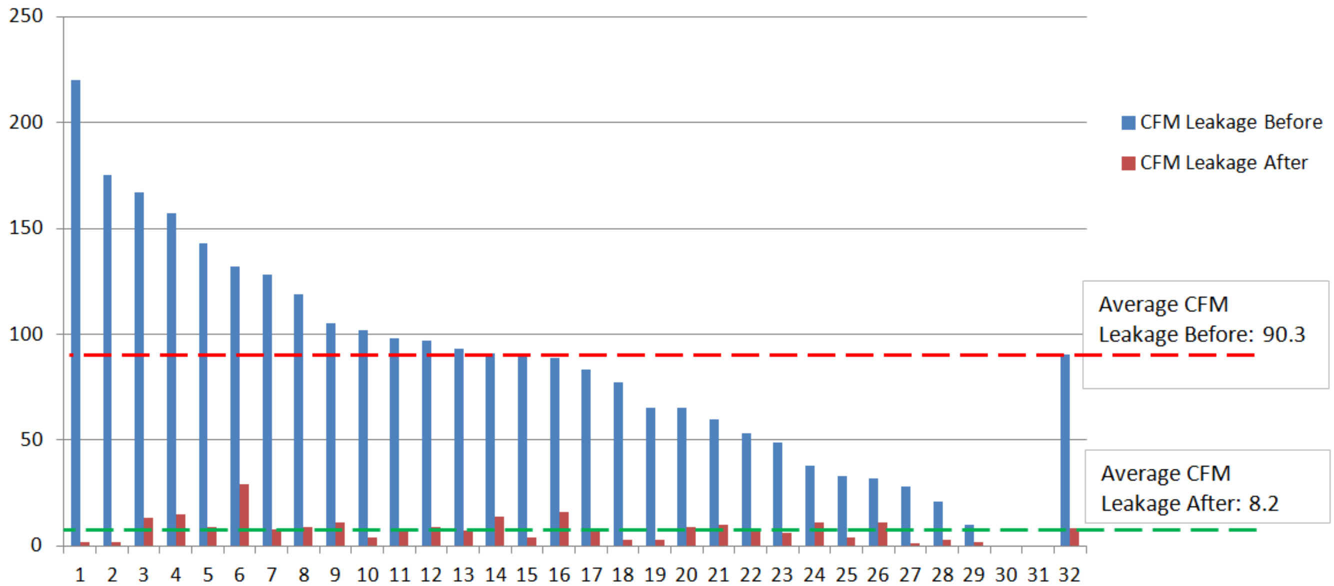

Figure 2. 29 Detached Single-Family Home Regional Case Study for Internal Duct Sealing Before-and-After Leakage Performance

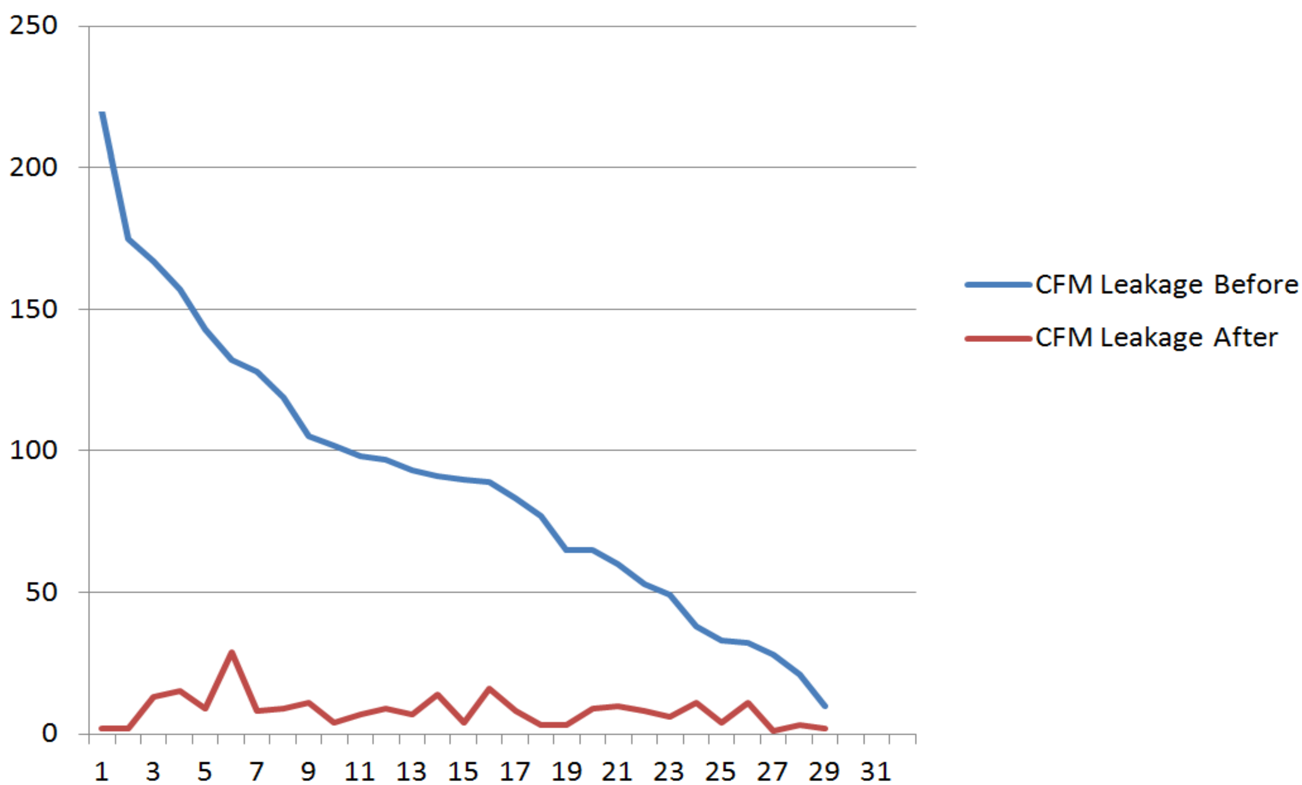

Figure 3. 29 Detached Single-Family Home Regional Case Study for Internal Duct Sealing Before-and-After Leakage Performance

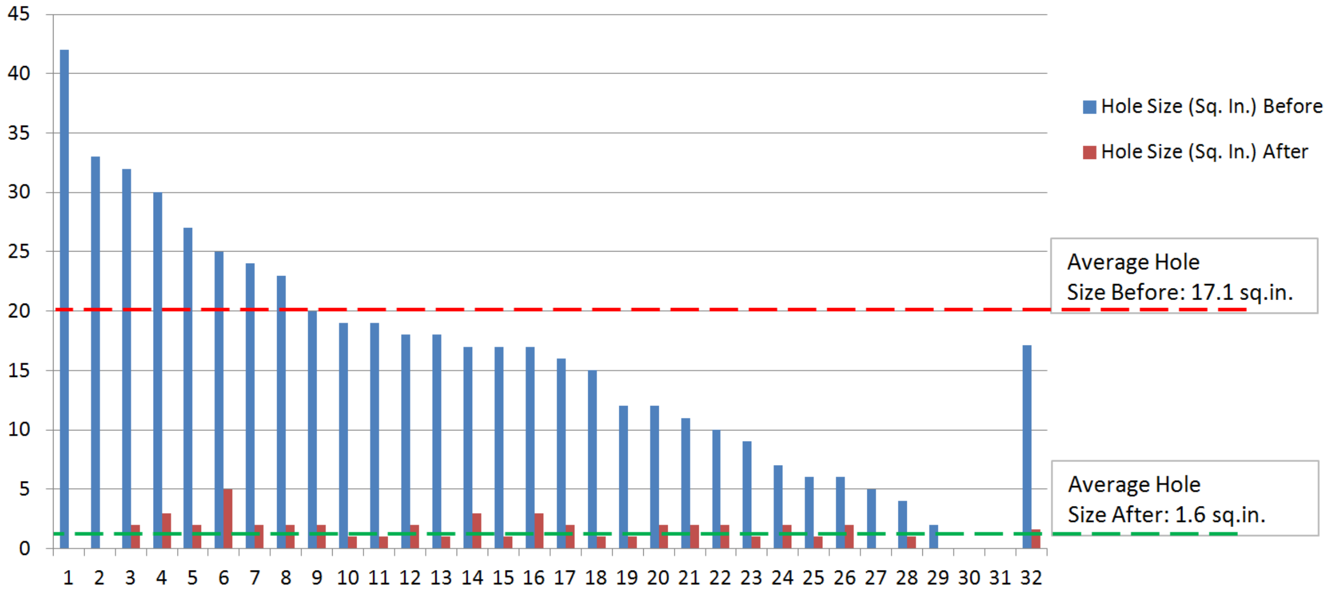

Figure 4. 29 Detached Single-Family Home Regional Case Study for Internal Duct Sealing Before-and-After Hole Size Comparable

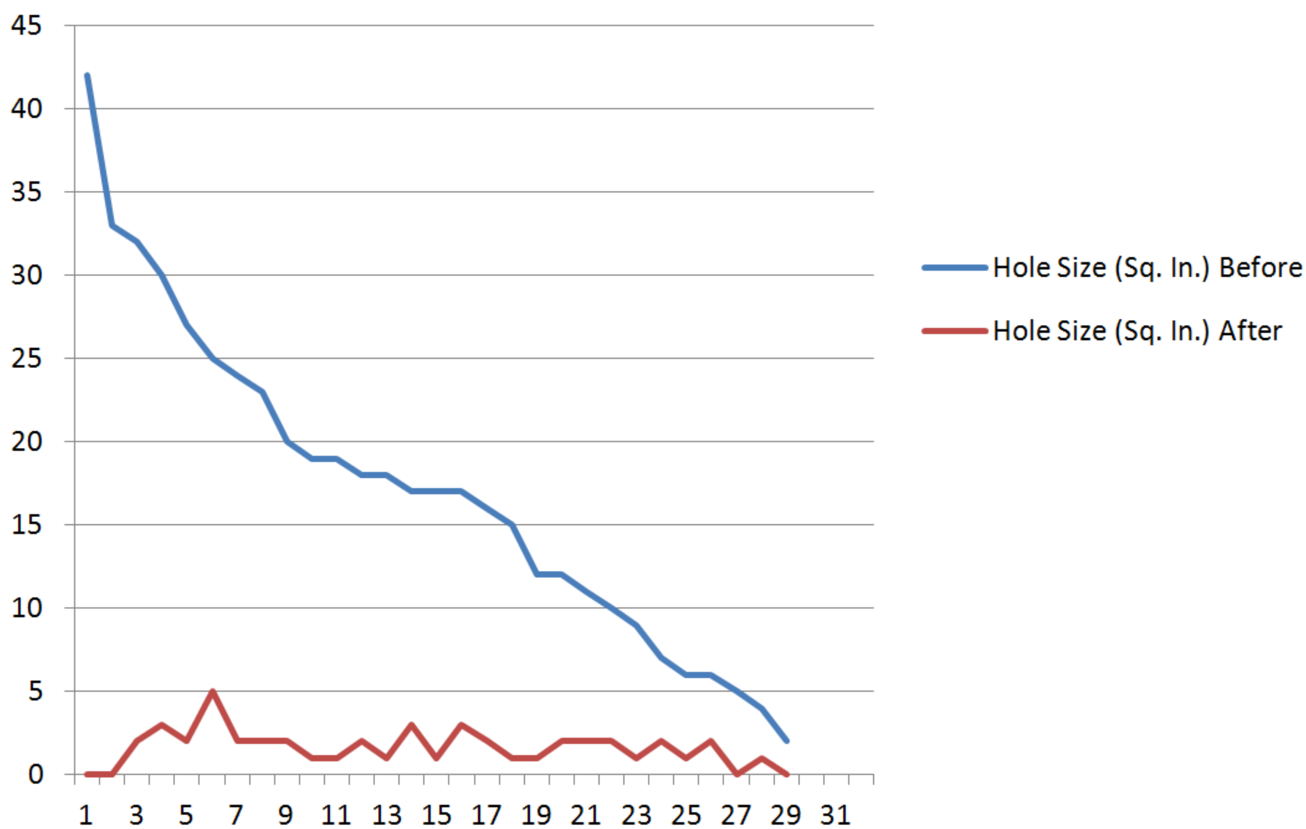

Figure 5. 29 Detached Single-Family Home Regional Case Study for Internal Duct Sealing Before-and-After Hole Size Comparable

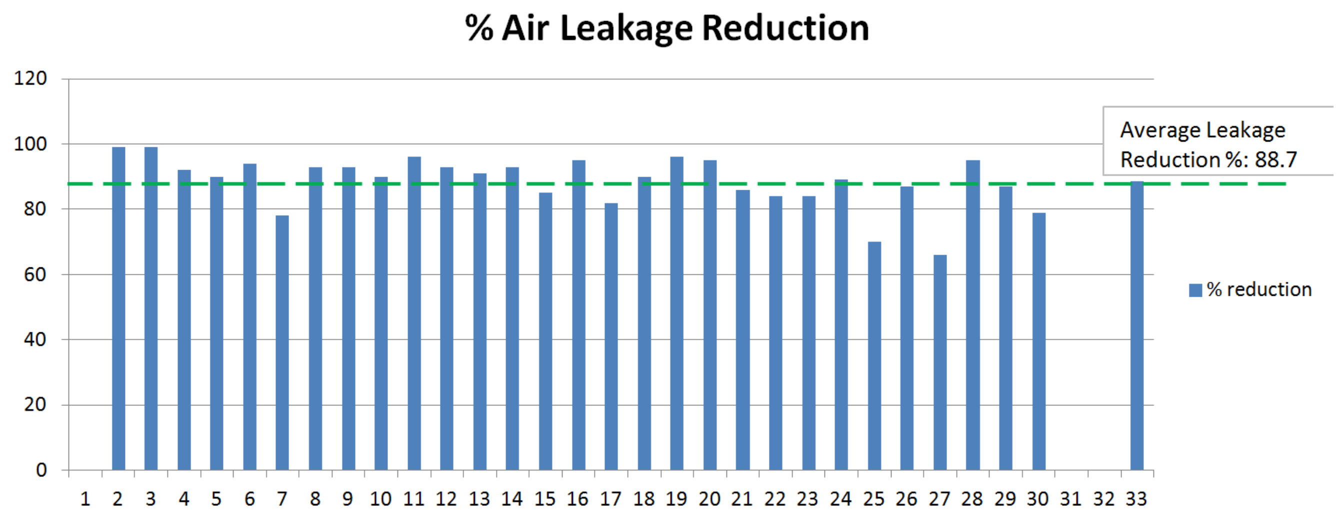

Figure 6. 29 Detached Single-Family Home Regional Case Study for Internal Duct Sealing Before-and-After Air Leakage Reduction

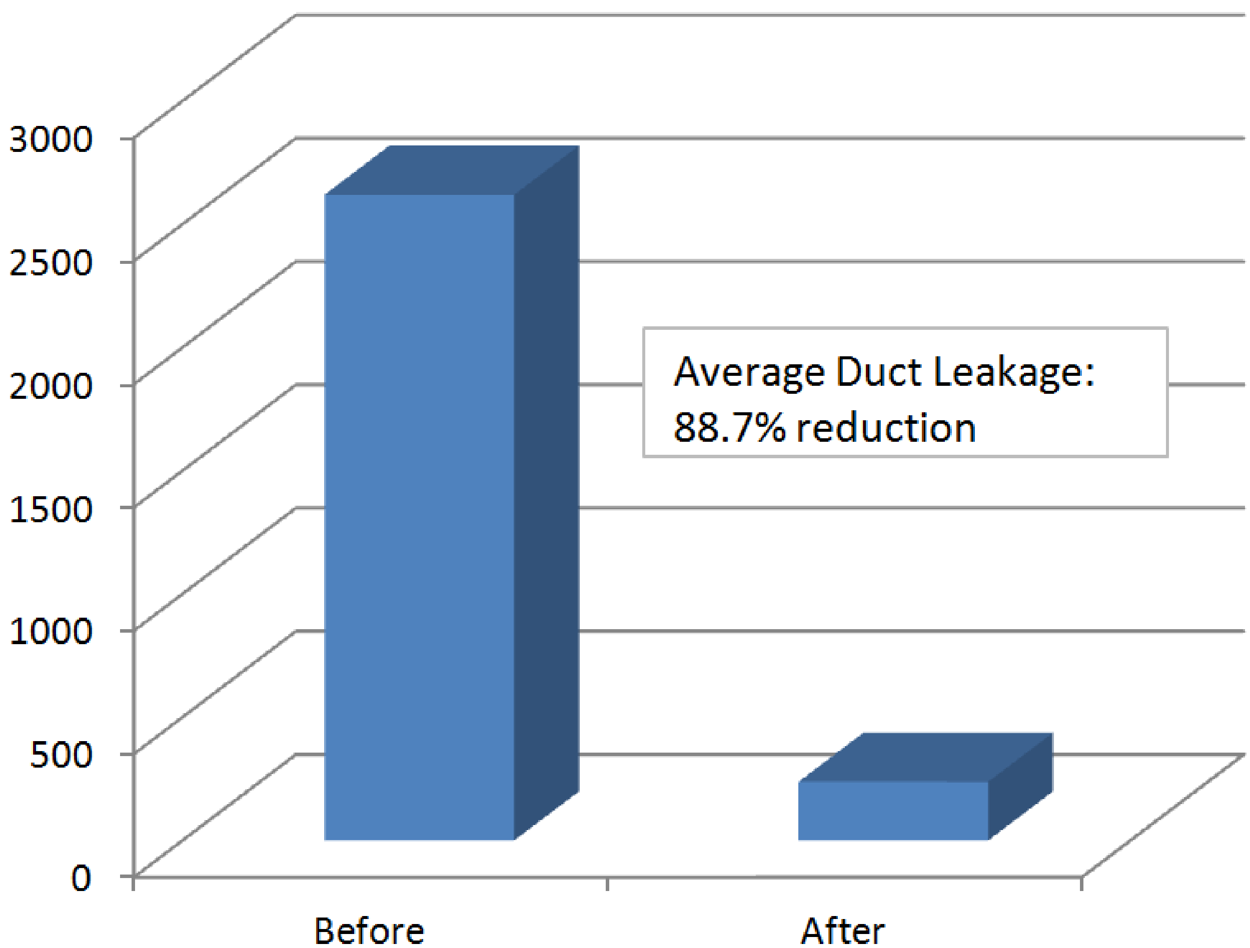

Figure 7. 29 Detached Single-Family Home Regional Case Study for Internal Duct Sealing Before-and-After Air Leakage Reduction

Appendix D – NEPDEER Home Case Study Review

Energy Audit and Historical Utility Data Compilation

Energy Audit and Historical Utility Data Comparison											8-Nov-14
House No.	SF Area	# Occupants	EPA (HEY) Score	kbtu/yr	Total EUI	HVAC EUI	Baseload EUI	Intensity	Baseload (kbtu)	Summer Cooling HVAC (kbtu)	Winter Heating HVAC (kbtu)
					kbtu/sf/yr	kbtu/sf/yr	kbtu/sf/yr	mbtu/person/yr	water heating, appliances, electronics, lighting	(June - September)	(October - May)
A1	1,654	2	4.1	67,468	41	25	16	34	26,615	6,956	33,898
A2	3,352	3	2.8	156,641	47	37	10	52	33,473	13,777	109,390
A3	3,409	10	9.5	104,254	31	17	14	10	47,464	10,072	46,718
B1											
B2	1,240	2	1.2	76,336	62	19	42	38	52,329	7,277	16,730
B3	2,609	2	9.5	70,022	27	20	7	35	18,933	2,790	48,298
B4	1,176	2	4.7	73,690	63	44	18	37	21,374	6,425	45,891
C1											
C2	1,750	4	7.1	103,848	59	39	20	26	35,054	4,728	64,067
D1	1,877	3	8.4	79,494	42	27	16	26	29,395	9,024	41,074
D2	3,100	3	6.4	109,576	35	24	11	37	35,254	9,333	64,989
F1	2,580	3	3.0	119,870	46	25	21	40	54,542	12,098	53,229
F2	1,992	3	5.1	90,920	46	25	21	30	41,232	12,351	37,337
Average	**1,903**	**2.8**	**4.8**	**80,932**	**38**	**23**	**15**	**28**	**30,436**	**7,295**	**43,202**

Figure 1. Detached Single-Family Home Regional Case Study - Energy Audit and Utility History Assessment. High and Low Homes (B1, C1) not included in averages

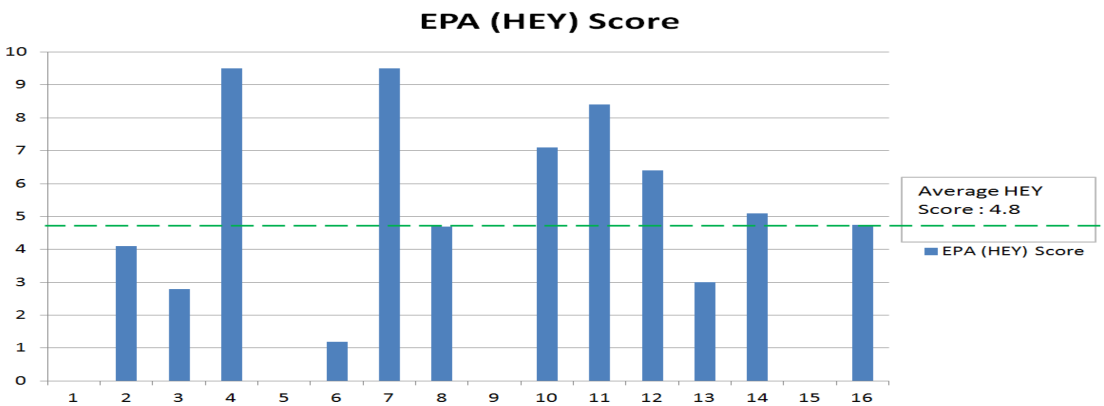

Figure 2. Average EPA Home Energy Yardstick Score is 4.8 out of a possible 10 points with 10 being the most efficient

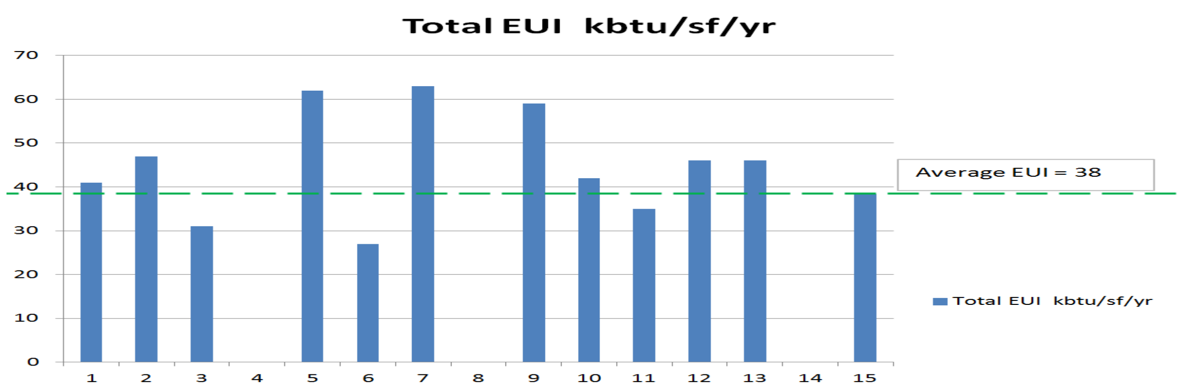

Figure 3. Average Total Energy Use Intensity (EUI) is 38. The lower the number the more energy efficient the home is.

Code	A1	
NEPDEER monitoring Data	no	
Historical Energy Use Data	yes	
NEPDEER audit	yes	
NEPDEER audit #	007	
County	Iredell	
State	NC	
Zip	28677	
Total Square Footage	1654	
Number of People	2	
CFM air leakage	1475	
Utility History Data Start date	May-12	
Utility History Data End date	Apr-13	
CDD 65	1,205	
HDD 65	3,021	
Total ElectricUse(kWh)	10,690	
Total Natural Gas Use(Therms)	310	
EPA Yardstick (HEY) Score	4.1	
Yearly kbtus	67,468	
EUI (kbtu/sf/yr)	41	
HVAC EUI	25	
Baseload EUI	16	
Intensity (mbtu/person/yr)	34	
Baseload (kbtu/month)	2,218	
Baseload - water heating, appliances, electronics, lighting kbtus	26,615	39%
Air Conditioning Summer (June-Sept) HVAC kbtus	6,956	10%
Space Heating Winter (Oct-May) HVAC kbtus	33,898	50%

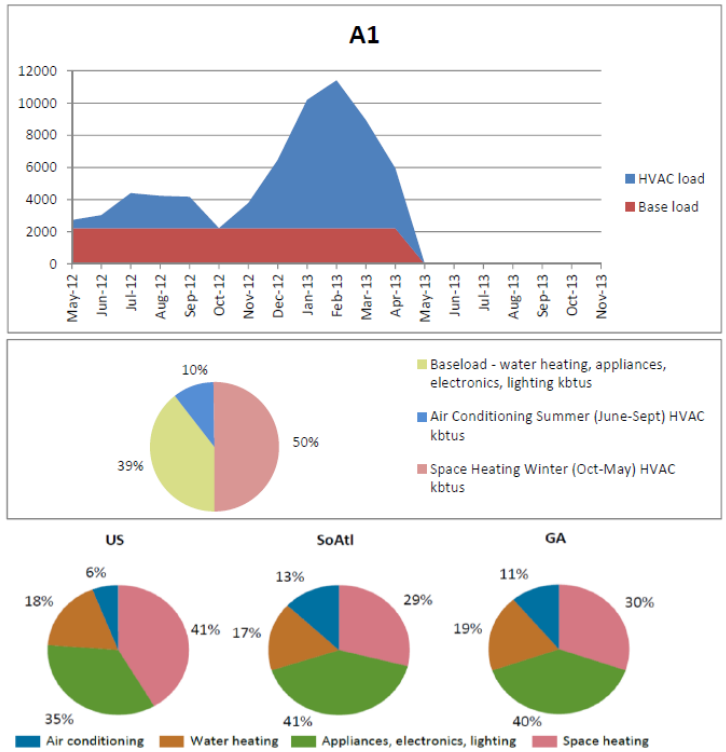

Figure 4. Home "A1" Detached Single-Family Home Regional Case Study - Energy Audit and Utility History Assessment

Code	A2	
NEPDEER monitoring Data	no	
Historical Energy Use Data	yes	
NEPDEER audit	yes	
NEPDEER audit #	014	
County	Mecklenburg	
State	NC	
Zip		
Total Square Footage	3352	
Number of People	3	
CFM air leakage	7440	
Utility History Data Start date	Jun-12	
Utility History Data End date	May-13	
CDD 65	1,718	
HDD 65	3,073	
Total ElectricUse(kWh)	12,827	
Total Natural Gas Use(Therms)	1,129	
EPA Yardstick (HEY) Score	2.8	
Yearly kbtus	156,641	
EUI (kbtu/sf/yr)	47	
HVAC EUI	37	
Baseload EUI	10	
Intensity (mbtu/person/yr)	52	
Baseload (kbtu/month)	2,789	
Baseload - water heating, appliances, electronics, lighting kbtus	33,473	21%
Air Conditioning Summer (June-Sept) HVAC kbtus	13,777	9%
Space Heating Winter (Oct-May) HVAC kbtus	109,390	70%

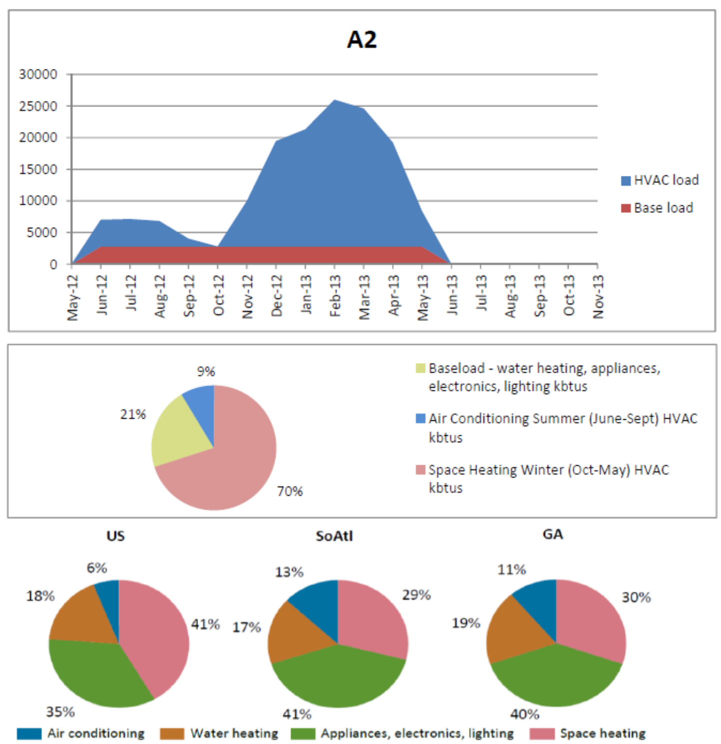

Figure 5. Home "A2" Detached Single-Family Home Regional Case Study - Energy Audit and Utility History Assessment

Code	A3	
NEPDEER monitoring Data	yes	
Historical Energy Use Data	yes	
NEPDEER audit	yes	
NEPDEER audit #	017	
County	Mecklenburg	
State	NC	
Zip		
Total Square Footage	3409	
Number of People	10	
CFM air leakage	2415	
Utility History Data Start date	Dec-12	
Utility History Data End date	Nov-13	
CDD 65	1,566	
HDD 65	3,304	
Total ElectricUse(kWh)	10,835	
Total Natural Gas Use(Therms)	673	
EPA Yardstick (HEY) Score	9.5	
Yearly kbtus	104,254	
EUI (kbtu/sf/yr)	31	
HVAC EUI	17	
Baseload EUI	14	
Intensity (mbtu/person/yr)	10	
Baseload (kbtu/month)	3,955	
Baseload - water heating, appliances, electronics, lighting kbtus	47,464	46%
Air Conditioning Summer (June-Sept) HVAC kbtus	10,072	10%
Space Heating Winter (Oct-May) HVAC kbtus	46,718	45%

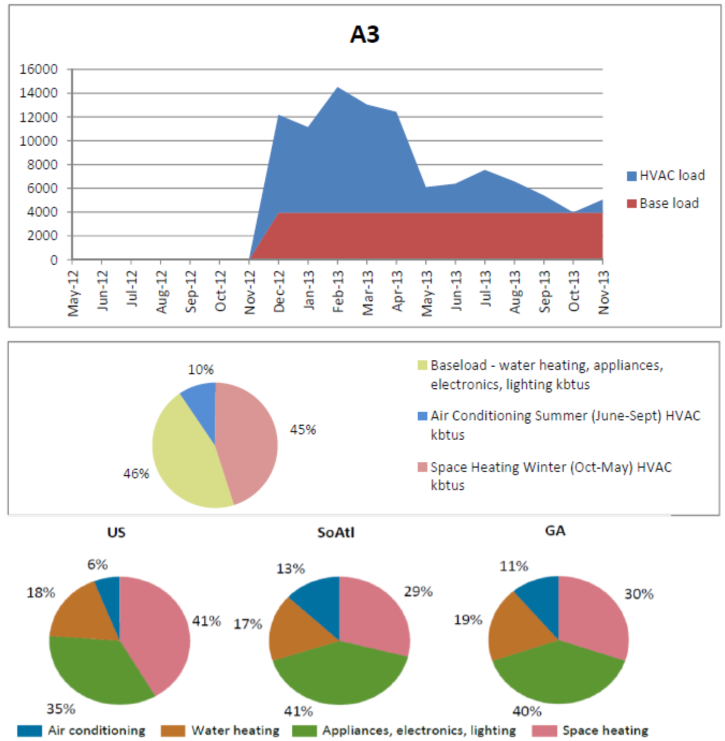

Figure 6. Home "A3" Detached Single-Family Home Regional Case Study - Energy Audit and Utility History Assessment

Code	B1	
NEPDEER monitoring Data	no	
Historical Energy Use Data	yes	
NEPDEER audit	no	
NEPDEER audit #	n/a	
County	Mecklenburg	
State	NC	
Zip		
Total Square Footage	1600	
Number of People	5	
CFM air leakage		
Utility History Data Start date	Aug-12	
Utility History Data End date	Jul-13	
CDD 65	1,705	
HDD 65	3,322	
Total ElectricUse(kWh)	27,256	
Total Natural Gas Use(Therms)	1,005	
EPA Yardstick (HEY) Score	0.3	
Yearly kbtus	193,477	
EUI (kbtu/sf/yr)	121	
HVAC EUI	66	
Baseload EUI	55	
Intensity (mbtu/person/yr)	39	
Baseload (kbtu/month)	7,293	
Baseload - water heating, appliances, electronics, lighting kbtus	87,513	45%
Air Conditioning Summer (June-Sept) HVAC kbtus	24,180	12%
Space Heating Winter (Oct-May) HVAC kbtus	81,784	42%

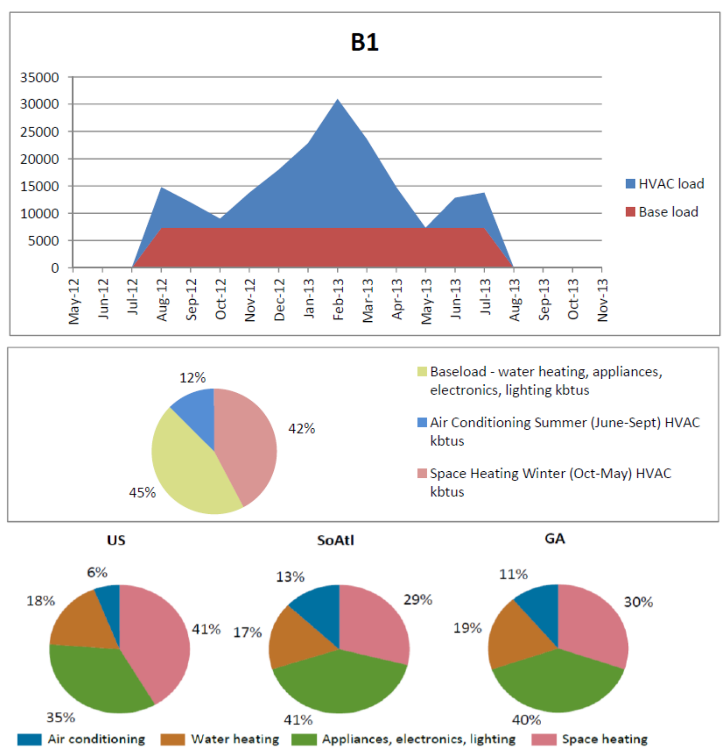

Figure 7. Home "B1" Detached Single-Family Home Regional Case Study - Energy Audit and Utility History Assessment

Code	B2	
NEPDEER monitoring Data	no	
Historical Energy Use Data	yes	
NEPDEER audit	yes	
NEPDEER audit #	012	
County	Mecklenburg	
State	NC	
Zip		
Total Square Footage	1240	
Number of People	2	
CFM air leakage	2917	
Utility History Data Start date	Oct-12	
Utility History Data End date	Sep-13	
CDD 65	1,571	
HDD 65	3,310	
Total ElectricUse(kWh)	17,303	
Total Natural Gas Use(Therms)	173	
EPA Yardstick (HEY) Score	1.2	
Yearly kbtus	76,336	
EUI (kbtu/sf/yr)	62	
HVAC EUI	19	
Baseload EUI	42	
Intensity (mbtu/person/yr)	38	
Baseload (kbtu/month)	4,361	
Baseload - water heating, appliances, electronics, lighting kbtus	52,329	69%
Air Conditioning Summer (June-Sept) HVAC kbtus	7,277	10%
Space Heating Winter (Oct-May) HVAC kbtus	16,730	22%

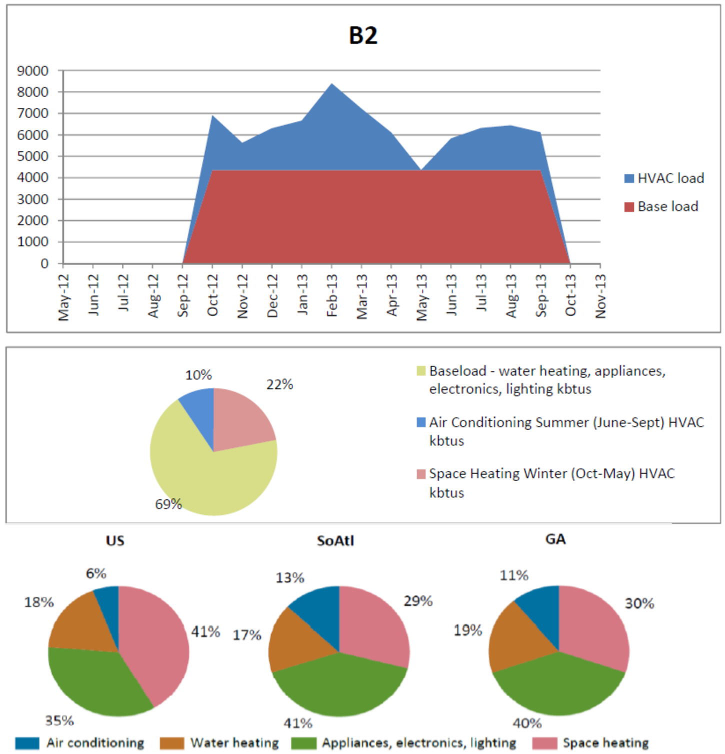

Figure 8. Home "B2" Detached Single-Family Home Regional Case Study - Energy Audit and Utility History Assessment

Code	B3	
NEPDEER monitoring Data	no	
Historical Energy Use Data	yes	
NEPDEER audit	yes	
NEPDEER audit #	021	
County	Mecklenburg	
State	NC	
Zip		
Total Square Footage	2609	
Number of People	2	
CFM air leakage	4170	
Utility History Data Start date	Sep-12	
Utility History Data End date	Aug-13	
CDD 65	1,695	
HDD 65	3,310	
Total ElectricUse(kWh)	4,084	
Total Natural Gas Use(Therms)	561	
EPA Yardstick (HEY) Score	9.5	
Yearly kbtus	70,022	
EUI (kbtu/sf/yr)	27	
HVAC EUI	20	
Baseload EUI	7	
Intensity (mbtu/person/yr)	35	
Baseload (kbtu/month)	1,578	
Baseload - water heating, appliances, electronics, lighting kbtus	18,933	27%
Air Conditioning Summer (June-Sept) HVAC kbtus	2,790	4%
Space Heating Winter (Oct-May) HVAC kbtus	48,298	69%

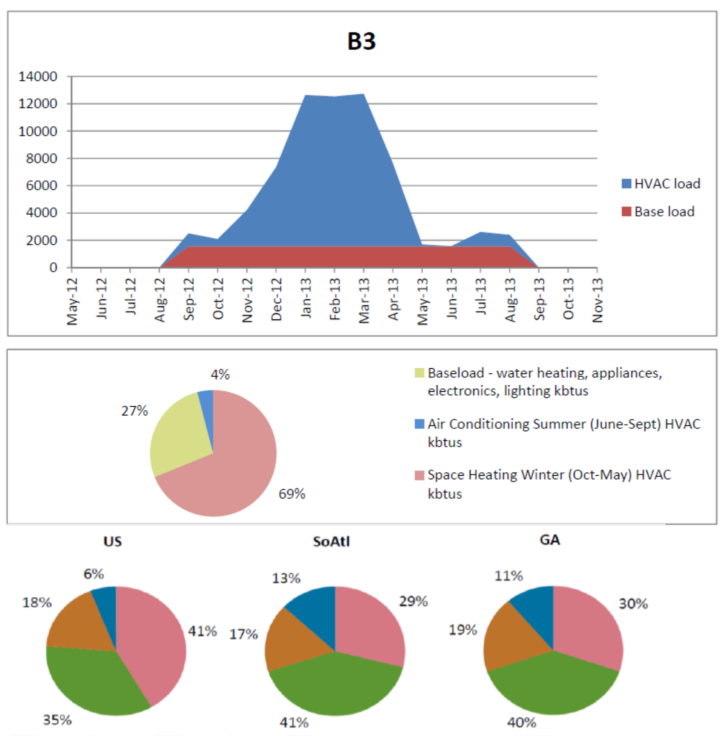

Figure 9. Home "B3" Detached Single-Family Home Regional Case Study - Energy Audit and Utility History Assessment

Code	B4	
NEPDEER monitoring Data	no	
Historical Energy Use Data	yes	
NEPDEER audit	yes	
NEPDEER audit #	003	
County	Gaston	
State	NC	
Zip		
Total Square Footage	1176	
Number of People	2	
CFM air leakage	5100	
Utility History Data Start date	Aug-12	
Utility History Data End date	Jul-13	
CDD 65	1,514	
HDD 65	3,432	
Total ElectricUse(kWh)	9,056	
Total Natural Gas Use(Therms)	428	
EPA Yardstick (HEY) Score	4.7	
Yearly kbtus	73,690	
EUI (kbtu/sf/yr)	63	
HVAC EUI	44	
Baseload EUI	18	
Intensity (mbtu/person/yr)	37	
Baseload (kbtu/month)	1,781	
Baseload - water heating, appliances, electronics, lighting kbtus	21,374	29%
Air Conditioning Summer (June-Sept) HVAC kbtus	6,425	9%
Space Heating Winter (Oct-May) HVAC kbtus	45,891	62%

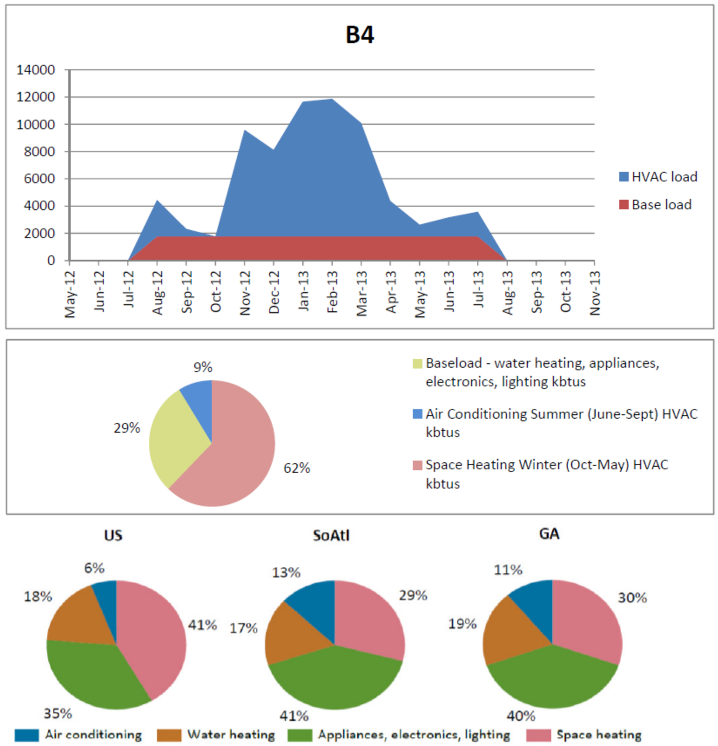

Figure 10. Home "B4" Detached Single-Family Home Regional Case Study - Energy Audit and Utility History Assessment

Code	C1	
NEPDEER monitoring Data	no	
Historical Energy Use Data	yes	
NEPDEER audit	yes	
NEPDEER audit #	009	
County	Mecklenburg	
State	NC	
Zip		
Total Square Footage	1408	
Number of People	1	
CFM air leakage	4906	
Utility History Data Start date	Aug-12	
Utility History Data End date	Jul-13	
CDD 65	1,705	
HDD 65	3,322	
Total ElectricUse(kWh)	11,314	
Total Natural Gas Use(Therms)	36	
EPA Yardstick (HEY) Score	5.2	
Yearly kbtus	42,204	
EUI (kbtu/sf/yr)	30	
HVAC EUI	9	
Baseload EUI	21	
Intensity (mbtu/person/yr)	42	
Baseload (kbtu/month)	2,412	
Baseload - water heating, appliances, electronics, lighting kbtus	28,949	69%
Air Conditioning Summer (June-Sept) HVAC kbtus	9,274	22%
Space Heating Winter (Oct-May) HVAC kbtus	3,981	9%

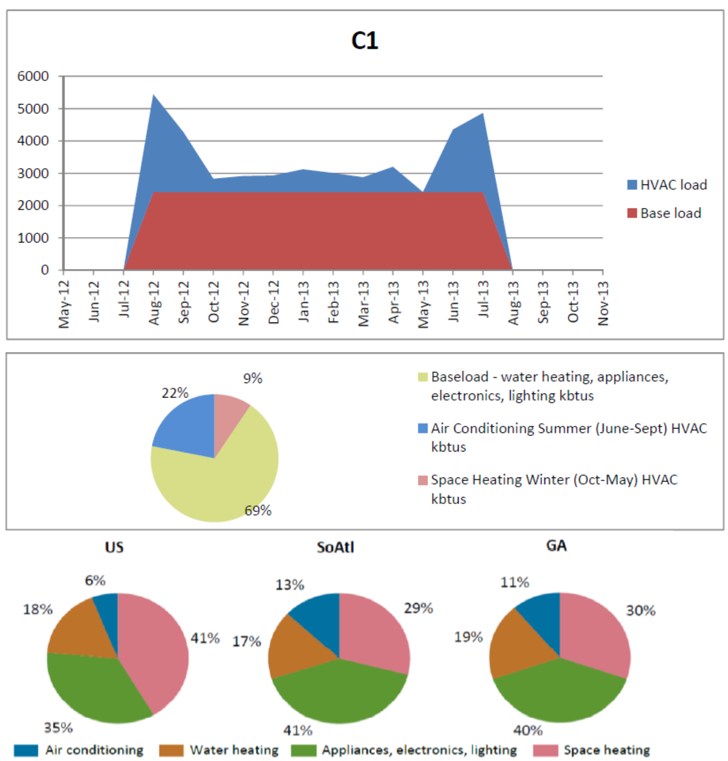

Figure 11. Home "C1" Detached Single-Family Home Regional Case Study - Energy Audit and Utility History Assessment

Code	C2	
NEPDEER monitoring Data	no	
Historical Energy Use Data	yes	
NEPDEER audit	no	
NEPDEER audit #	n/a	
County	Mecklenburg	
State	NC	
Zip		
Total Square Footage	1750	
Number of People	4	
CFM air leakage		
Utility History Data Start date	Aug-12	
Utility History Data End date	Jul-13	
CDD 65	1,705	
HDD 65	3,322	
Total ElectricUse(kWh)	7,317	
Total Natural Gas Use(Therms)	789	
EPA Yardstick (HEY) Score	7.1	
Yearly kbtus	103,848	
EUI (kbtu/sf/yr)	59	
HVAC EUI	39	
Baseload EUI	20	
Intensity (mbtu/person/yr)	26	
Baseload (kbtu/month)	2,921	
Baseload - water heating, appliances, electronics, lighting kbtus	35,054	34%
Air Conditioning Summer (June-Sept) HVAC kbtus	4,728	5%
Space Heating Winter (Oct-May) HVAC kbtus	64,067	62%

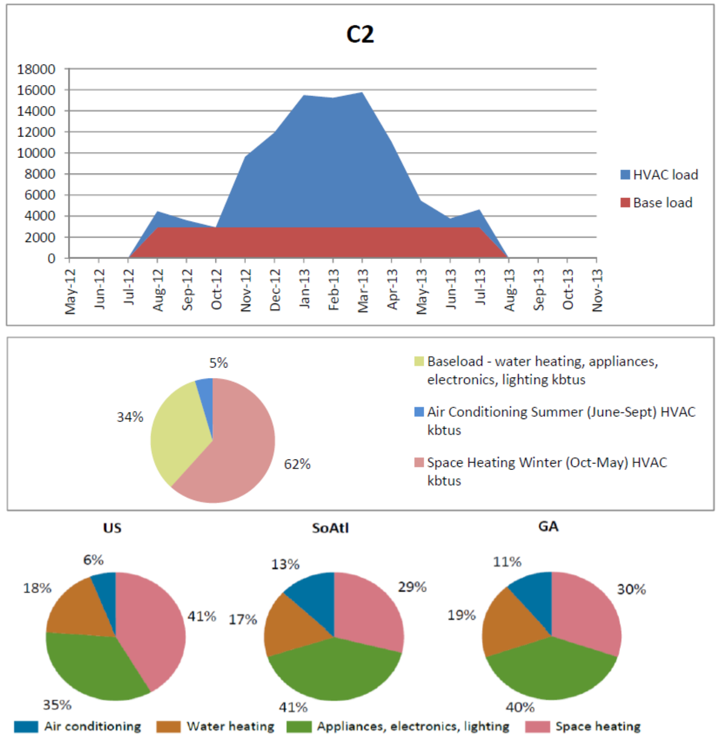

Figure 12. Home "C2" Detached Single-Family Home Regional Case Study - Energy Audit and Utility History Assessment

Code	D1	
NEPDEER monitoring Data	yes	
Historical Energy Use Data	yes	
NEPDEER audit	yes	
NEPDEER audit #	019	
County	Mecklenburg	
State	NC	
Zip		
Total Square Footage	1877	
Number of People	3	
CFM air leakage	4170	
Utility History Data Start date	Jul-12	
Utility History Data End date	Jun-13	
CDD 65	1,788	
HDD 65	3,259	
Total ElectricUse(kWh)	6,186	
Total Natural Gas Use(Therms)	584	
EPA Yardstick (HEY) Score	8.4	
Yearly kbtus	79,494	
EUI (kbtu/sf/yr)	42	
HVAC EUI	27	
Baseload EUI	16	
Intensity (mbtu/person/yr)	26	
Baseload (kbtu/month)	2,450	
Baseload - water heating, appliances, electronics, lighting kbtus	29,395	37%
Air Conditioning Summer (June-Sept) HVAC kbtus	9,024	11%
Space Heating Winter (Oct-May) HVAC kbtus	41,074	52%

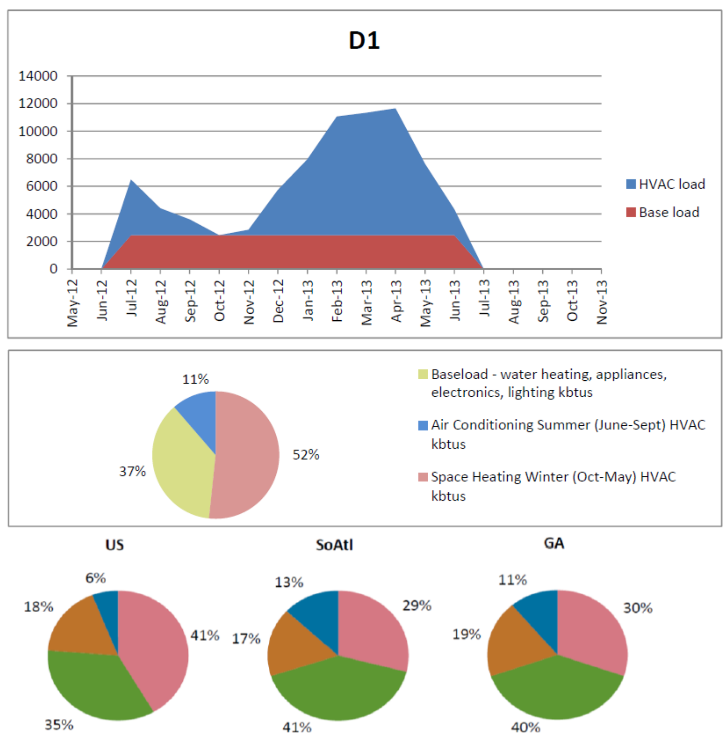

Figure 13. Home "D1" Detached Single-Family Home Regional Case Study - Energy Audit and Utility History Assessment

Code	D2	
NEPDEER monitoring Data	no	
Historical Energy Use Data	yes	
NEPDEER audit	yes	
NEPDEER audit #	020	
County	Mecklenburg	
State	NC	
Zip		
Total Square Footage	3100	
Number of People	3	
CFM air leakage	3000	
Utility History Data Start date	Aug-12	
Utility History Data End date	Jul-13	
CDD 65	1,705	
HDD 65	3,322	
Total ElectricUse(kWh)	9,699	
Total Natural Gas Use(Therms)	765	
EPA Yardstick (HEY) Score	6.4	
Yearly kbtus	109,576	
EUI (kbtu/sf/yr)	35	
HVAC EUI	24	
Baseload EUI	11	
Intensity (mbtu/person/yr)	37	
Baseload (kbtu/month)	2,938	
Baseload - water heating, appliances, electronics, lighting kbtus	35,254	32%
Air Conditioning Summer (June-Sept) HVAC kbtus	9,333	9%
Space Heating Winter (Oct-May) HVAC kbtus	64,989	59%

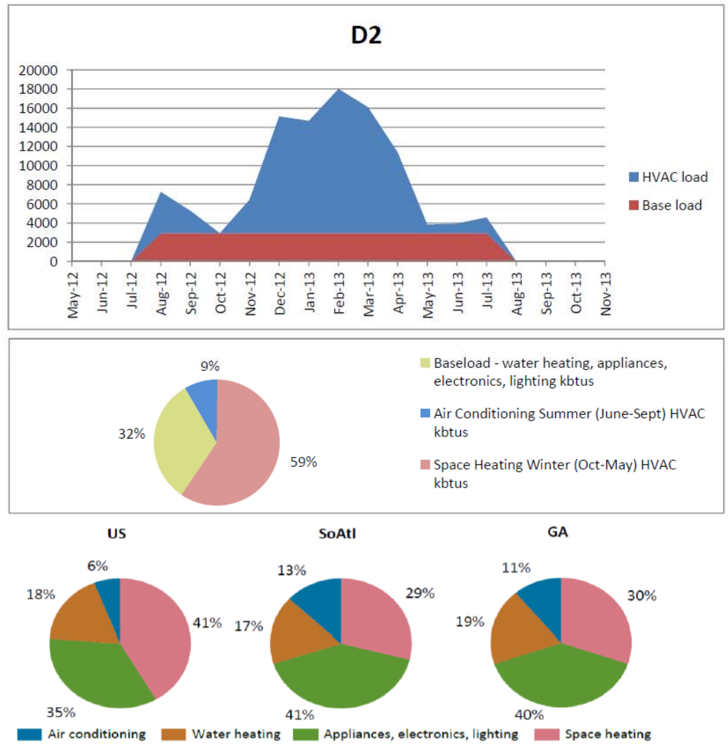

Figure 14. Home "D2" Detached Single-Family Home Regional Case Study - Energy Audit and Utility History Assessment

Code	F1	
NEPDEER monitoring Data	yes	
Historical Energy Use Data	yes	
NEPDEER audit	yes	
NEPDEER audit #	024	
County	York	
State	SC	
Zip	29730	
Total Square Footage	2580	
Number of People	3	
CFM air leakage	4600	
Utility History Data Start date	Oct-12	
Utility History Data End date	Sep-13	
CDD 65	1,545	
HDD 65	3,434	
Total ElectricUse(kWh)	13,847	
Total Natural Gas Use(Therms)	726	
EPA Yardstick (HEY) Score	3	
Yearly kbtus	119,870	
EUI (kbtu/sf/yr)	46	
HVAC EUI	25	
Baseload EUI	21	
Intensity (mbtu/person/yr)	40	
Baseload (kbtu/month)	4,545	
Baseload - water heating, appliances, electronics, lighting kbtus	54,542	46%
Air Conditioning Summer (June-Sept) HVAC kbtus	12,098	10%
Space Heating Winter (Oct-May) HVAC kbtus	53,229	44%

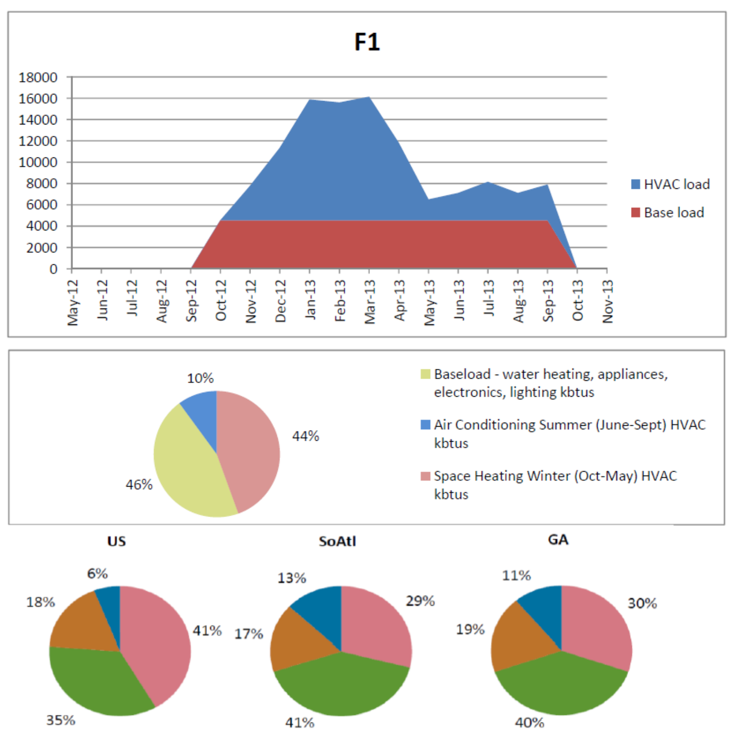

Figure 15. Home "F1" Detached Single-Family Home Regional Case Study - Energy Audit and Utility History Assessment

Code	F2	
NEPDEER monitoring Data	no	
Historical Energy Use Data	yes	
NEPDEER audit	no	
NEPDEER audit #	n/a	
County	Mecklenburg	
State	NC	
Zip		
Total Square Footage	1992	
Number of People	3	
CFM air leakage		
Utility History Data Start date	Aug-12	
Utility History Data End date	Jul-13	
CDD 65	1,705	
HDD 65	3,322	
Total ElectricUse(kWh)	11,410	
Total Natural Gas Use(Therms)	520	
EPA Yardstick (HEY) Score	5.1	
Yearly kbtus	90,920	
EUI (kbtu/sf/yr)	46	
HVAC EUI	25	
Baseload EUI	21	
Intensity (mbtu/person/yr)	30	
Baseload (kbtu/month)	3,436	
Baseload - water heating, appliances, electronics, lighting kbtus	41,232	45%
Air Conditioning Summer (June-Sept) HVAC kbtus	12,351	14%
Space Heating Winter (Oct-May) HVAC kbtus	37,337	41%

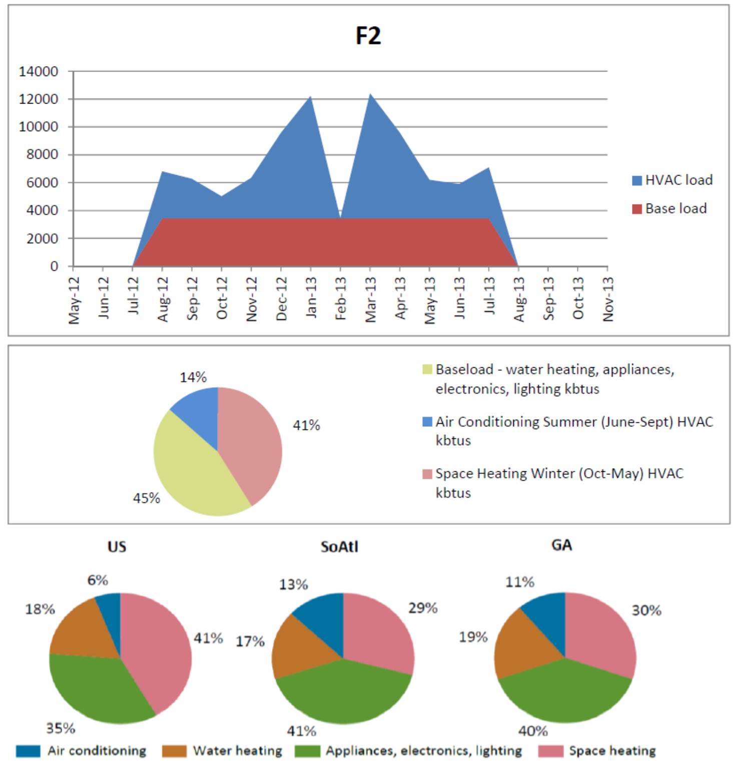

Figure 16. Home "F2" Detached Single-Family Home Regional Case Study - Energy Audit and Utility History Assessment