Rhode Island 2011 Baseline Study of Single-Family Residential New Construction

Final Report

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National Grid

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Executive Summary

The 2011 Baseline study was conducted with several objectives in mind. The primary objective is to provide a study of the characteristics of single-family homes recently completed in Rhode Island and permitted under the 2009 International Energy Conservation Code (IECC) that did not participate in the Rhode Island Residential New Construction Program (RNC Program) that can be used to update User Defined Reference Home (UDRH) assumptions used in calculating Program savings. Secondary objectives are:

- Conducting a full HERS rating for each home using REM/Rate™ software
- Providing a comparison of 2011 baseline study homes to single-family homes completed through the 2011 Program
- Using 2009 IECC compliance reports produced by REM/Rate to assess how the baseline homes would likely perform under different performance based compliance paths
- Assessing code compliance using the 2009 IECC checklist developed by Pacific Northwest National Laboratory (PNNL)

Throughout this Executive Summary there are links to sections of the report that provide more detail on the information being presented. Readers may place the cursor on the link and use control/click to go directly to the section of the report that provides more detail.

Background

Audits of 40 homes were conducted from early August through early November of 2011; HERS (Home Energy Rating System) ratings were performed on all 40 homes and HVAC performance testing was conducted at 16 homes. Manual J assessments were done for all inspected homes. The REM/Rate software used for the HERS ratings provided 2009 IECC code compliance reports for multiple compliance paths for each home. The owners of audited homes were asked to complete a short survey while their homes were being inspected. The survey addressed, among other things, how the home was purchased, the importance of getting an energy-efficient home, who specified various home components, and owners' perceptions of the overall energy-efficiency of their home and its various components.

The sampling plan matched the percentage of on-site inspections conducted in a county to the percentage of state level permits issued in that county and targeted a mix of custom and spec built homes. In order to reflect the mix of spec and custom single-family homes in the 2011 Rhode Island Program, the data are weighted by 90% for spec and 10% for custom homes. Both unweighted and weighted results are provided throughout this report, with the emphasis on weighted results. See Section 2 Sampling Methodology.

The remainder of this Executive Summary summarizes the UDRH inputs estimated; comparisons with individual 2009 IECC prescriptive insulation requirements; potential compliance rates under various compliance paths based on the compliance reports available from the REM/Rate software used to produce HERS ratings and the 2009 IECC checklist developed by PNNL; and the results of the Manual J assessments and HVAC performance testing. Also addressed are the comparison of 2011 baseline homes to 2011 Program homes and the on-site survey completed by the owners of inspected homes. These are very high level summaries that include links to the report sections that provide more detailed information.

Preliminary UDRH Inputs

Table ES 1 on the next page compares 2011 Baseline Study findings to selected current UDRH inputs.[1] The 2011 Baseline UDRH inputs are preliminary estimates based on study findings weighted to reflect the mix of single-family spec and custom housing in the 2011 Program. See Section 3 Preliminary UDRH Inputs for detailed tables showing the data used to develop the preliminary estimates of UDRH inputs. The Program Administrator will review these preliminary UDRH estimates and develop a final set of UDRH inputs that incorporates additional information based on experience administering the Program as well as information on specific measures that were found in either none or very few of the audited baseline homes. The final UDRH inputs will be provided as an Addendum to this report.

As shown, the 2011 baseline preliminary estimated UDRH inputs suggest that the current UDRH assumptions underestimate the efficiency of most current building practices and equipment. In a few cases, study findings suggest current UDRH inputs may overestimate the efficiency of current building practices. Preliminary UDRH input estimates are higher energy efficiency than current UDRH inputs for the following building characteristics:

- Flat and cathedral ceiling U-values
- Foundation wall R-value
- Duct Insulation R-values
- Window U-value
- Air infiltration ACH50
- Natural gas and propane air and hydronic distribution heating system AFUE
- Oil-fired hydronic distribution heating system AFUE
- Cooling and water heating system efficiencies

Preliminary UDRH input estimates are lower energy efficiency than current UDRH inputs for the following characteristic:

- Wall U-value
- Floor over unconditioned basement U-value

[1] Several UDRH inputs are U-values. U-values are the overall heat transfer coefficient for the entire wall, floor or ceiling assembly, not just the insulation. The lower the U-value is, the more energy efficient the assembly. U-values calculated using REM/Rate software account for the R-value of framing members, the R-value of other components such as air barriers and drywall, the R-value of the insulation, and the quality of the insulation installation. If insulation is compressed, or there are gaps, the energy efficiency of the assembly is lower and the U-value is higher.

- Oil-fired air distribution heating system AFUE
- Duct leakage CFM25/100 Sq. Ft.

Table ES 1: Comparison of Current and Preliminary Estimated UDRH Inputs

Building Characteristic	Current UDRH Inputs	2011 Baseline Preliminary UDRH Input Estimates	Number of Baseline Homes or Systems
Wall U-value	U_0=.0.065	U_0=0.073	40 Homes
Wall Insulation R-value (Not a UDRH Input)**	R-20	R-17.75	40 Homes
Flat Ceiling U-value	U_0=0.058	U_0=0.051	35 Homes
Flat Ceiling Insulation R-value (Not a UDRH Input)**	R-31	R-34.6	35 Homes
Cathedral Ceiling U-value	U_0= 0.057	U_0=0.044	19 Homes
Cathedral Ceiling Insulation R-value (Not a UDRH Input)**	R-29.6	R-32.8	19 Homes
Floor over Unconditioned Space U-value	U_0=0.04	U_0=0.12	26 Homes
Floor over Unconditioned Space Insulation R-value (Not a UDRH Input)**	R-30	R-17.6	27 Homes
Foundation Wall Insulation R-value (conditioned basements)	R=13	R=18.6	4 Homes
Window U-value and SHGC	U=0.35 SHGC=0.35	U=0.34 SHGC=0.31	5 Homes Plus Secondary Information
Air Infiltration ACH50	6.72 ACH50	5.96 ACH50	38 Homes
Gas* Fuel Fired Air Distribution Heating Systems (Furnaces and Hydro-Air)	89.2 AFUE	92.2 AFUE	26 Heating Systems
Gas* Fuel Fired Hydronic Distribution Heating Systems (Hot Water Boilers)	81.7 AFUE	88.7 AFUE	10 Heating Systems
All Gas* fuel Fired Heating Systems	88.5 AFUE	91.3 AFUE	36 Heating Systems
Oil Fuel Fired Air Distribution Heating Systems (Furnaces and Hydro-Air)	83.9 AFUE	81.6 AFUE	2 Heating Systems
Oil Fuel Fired Hydronic Distribution Heating Systems (Hot Water Boilers)	84.4 AFUE	86.0 AFUE	4 Heating Systems
All Oil fuel Fired Systems	84.3 AFUE	84.9 AFUE	6 Heating Systems
Gas* Domestic Stand Alone Storage Tank Water Heater Energy Factor	0.58 EF	0.63 EF	8 Water Heaters
Cooling Efficiency SEER (Seasonal Energy Efficiency Ratio)	13.0 SEER	13.1 SEER	40 Cooling Systems
Duct Leakage (CFM25/100 Sq. Ft.)	14	20	22 Homes
Duct Insulation—Attic Supply Ducts	R=7.46	R=7.57	16 Homes
Duct Insulation—All Ducts in Unconditioned Space	R=4.68	R=6.62	24 Homes

*Gas includes both natural gas and propane equipment.

**Rows highlighted in gray for wall, ceiling and floor insulation are not UDRH inputs—the UDRH inputs are the U-values. The R-values are the insulation levels auditors observed when inspecting homes and are presented for information only for readers not that familiar with U-values.

Comparison to Individual 2009 IECC Prescriptive Insulation Requirements

There are three types of 2009 IECC requirements: mandatory, prescriptive and performance. Examples of mandatory requirements are air and duct sealing and equipment sizing. Prescriptive compliance path requirements address insulation, fenestration and lighting. Performance compliance path requirements are based on a home's performance using a simulation model, such as REM/Rate. The purpose of this study is not to assess code compliance for each inspected home, nor is it to evaluate code enforcement. Details on the compliance path utilized by each of the audited homes would be necessary to conduct such an evaluation, and this information was available for only some homes. The results presented here are not indicative of whether or not a home fully complied with code under an accepted compliance path. Throughout this report, 2009 IECC prescriptive path code requirements are simply used as reference points for comparison, with the percentages of inspected homes that meet or fail to meet prescriptive requirement levels presented. Comparing what was observed in inspected homes to specific prescriptive insulation requirements serves as a tool for assessing how many homes, regardless of what compliance path they followed, met those requirements.

Although the purpose of this study is not to assess code compliance for each inspected home, results clearly show room for improving the energy efficiency of new homes. Almost all inspected homes, 95%, have at least one instance where the R-value of installed insulation is below 2009 IECC prescriptive insulation requirements or mandatory duct insulation requirements:[2]

- Wood framed wall insulation of R-20 or R-13 cavity insulation plus R-5 insulated sheathing
- Conditioned basement foundation wall insulation of R-10 continuous or R-13 cavity
- Ceiling insulation of R-38 (Allows up to 500 square feet of vaulted ceiling area to be R-30)
- Floor insulation over unconditioned spaces of R-30 or framing cavity filled
- Attic supply duct insulation of R-8 and all other ducts in unconditioned space insulated to R-6

Table ES 2 on the next page categorizes inspected homes by what applicable prescriptive insulation requirements were not met. As shown, 23% of spec and 21% of custom homes, for a weighted average of 23%, did not meet prescriptive wall, ceiling and floor insulation requirements; 23% of spec and 7% of custom homes, for a weighted average of 21%, did not meet prescriptive wall, floor and duct insulation requirements; 15% of spec and 14% of custom homes, for a weighted average of 15%, met all applicable prescriptive insulation requirements

[2] Note that two building components are not addressed here—windows and slab floors. Documented U-value and SHGC information for windows was available for a limited number of homes where the original NFRC (National Fenestration Rating Council) sticker was visible. Auditors were unable to observe underneath the slabs and, therefore, were able neither to confirm the existence nor record the R-values of slab floor insulation in most homes.

except for exterior wall insulation. Only two homes, one spec and one custom, met all applicable insulation requirements for a weighted average of 4%. (See Appendix A 2009 IECC Prescriptive Code Compliance by Site for a list of the types of insulation applicable to each home, which prescriptive insulation requirements the home met, and which the home did not meet.)

Table ES 2: Applicable 2009 IECC Prescriptive Insulation Requirements Not Met

Applicable 2009 IECC Prescriptive Insulation Requirements Homes Failed to Meet	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=14)	Weighted (Spec/ Custom)
Wall, Ceiling & Floor	9 (23%)	6 (23%)	3 (21%)	23%
Wall, Floor & Duct	7 (18%)	6 (23%)	1 (7%)	21%
Wall	6 (15%)	4 (15%)	2 (14%)	15%
Ceiling	2 (5%)	1 (4%)	1 (7%)	4%
Ceiling & Floor	2 (5%)	1 (4%)	1 (7%)	4%
Wall & Duct	2 (5%)	0 (0%)	2 (14%)	1%
Wall, Ceiling & Duct	2 (5%)	2 (8%)	0 (0%)	7%
Wall, Ceiling, Floor & Duct	2 (5%)	1 (4%)	1 (7%)	4%
Ceiling, Floor & Duct	1 (3%)	0 (0%)	1 (7%)	1%
Exterior Wall & Foundation Wall	1 (3%)	1 (4%)	0 (0%)	3%
Exterior Wall, Foundation Wall & Ceiling	1 (3%)	1 (4%)	0 (0%)	3%
Floor	1 (3%)	0 (0%)	1 (7%)	1%
Foundation Wall & Duct	1 (3%)	1 (4%)	0 (0%)	3%
Wall & Ceiling	1 (3%)	1 (4%)	0 (0%)	3%
None: Met All Applicable Requirements	**2 (5%)**	**1 (4%)**	**1 (7%)**	**4%**

Compliance Reports

An exploratory analysis of 2009 IECC was conducted based on the 40 inspected homes using four different compliance paths and the 2009 IECC checklist developed by PNNL. The four compliance paths are the Prescriptive, Home Energy Rating, Annual Energy Cost, and Overall Building UA compliance paths. The Home Energy Rating, Annual Energy Cost, and Overall Building UA compliance paths were all assessed using reports and calculations available through the REM/Rate software. This approach allowed the evaluation team to leverage the REM/Rate files that were compiled for other pieces of this report and utilize those files for this analysis. Again, it should be noted that the purpose of this study is not to assess code compliance for each inspected home, nor is it to evaluate code enforcement. Details on the compliance path utilized by each of the audited homes would be necessary to conduct such an evaluation, and this information was not available for all homes; the compliance approach was determined for only 30 of the 40 inspected homes. Therefore, the results presented in this report are not indicative of actual code compliance but serve as a tool for assessing specific prescriptive measure compliance and how homes would likely perform under different performance based compliance paths.

Analysis of the REM/Rate compliance reports shows that homes would be likely to achieve the highest compliance using the Overall Building UA path (10% of all homes), followed by the Annual Energy Cost path (5% of all homes) and the Prescriptive path (5% of all homes). With respect to the 2009 IECC checklist, homes on average received 56% of possible checklist points; overall compliance with most individual checklist items is over 60%. It is important to note that Overall Building UA compliance was assessed using REM/Rate, not the more commonly used REScheck™ software. REM/Rate, unlike REScheck, accounts for the quality of the insulation installation when calculating overall UA values. For this reason it is much more difficult to achieve compliance using the REM/Rate UA approach as opposed to using REScheck. More details on code compliance can be found in the code compliance section of this report. See Section 5 Code Compliance.

Manual J Assessments and HVAC Performance

REM/Rate was used to assess heating and cooling system sizing. Results show most heating and cooling systems are oversized. The average heating equipment size ratio is 2.32, indicating that the average installed heating system rated capacity is 2.32 times the properly sized system capacity. For cooling systems, the average size ratio is 1.54, indicating that the average installed cooling system rated capacity is 1.54 times the properly sized system capacity. See Section 8.4 Heating and Cooling Equipment Sizing–Manual J.

In-field measurements were performed to calculate the actual cooling capacities and efficiencies of a sample of residential central air conditioning (CAC) systems throughout the state.[3] Twelve sites were ultimately included in the analysis; the average operating capacity was found to be 18.9% less than the rated capacity while the operating efficiency was found to be 5.5% less than the rated efficiency. More details on the HVAC performance testing analyses can be found in Section 8.3 HVAC Performance Testing.

Comparison to 2011 Program Single-Family Homes

Selected building characteristics of 2011 baseline homes are compared to the characteristics of single-family homes completed through the 2011 Program.[4] Average flat ceiling U-values, floor over unconditioned basement U-values and R-values, attic supply duct insulation R-values, air infiltration, duct leakage and HERS indices are all significantly less energy efficient in baseline homes; all these differences are statistically significant at the 90% confidence level. Differences in average conditioned/ambient wall R-values and U-values, flat ceiling R-values, cathedral

[3] Central heat pumps were included in the sample, but only the cooling performance of such systems was considered. Some homes used window air conditioning units, which were not included in the CAC analysis.
[4] Data on the characteristics of 2011 Program single-family homes were extracted from the REM/Rate files of all single-family homes completed through the 2011 Program.

ceiling U-values and R-values, foundation wall insulation levels, and insulation on ducts located in unconditioned space between Program and baseline homes are not statistically significant at the 90% confidence level. See Section 4 Comparison to 2011 Program Single-Family Homes.

On-site Homeowner Survey

Homeowners were asked to complete a short survey during the on-site inspections. The homeowners are a diverse group with representation across an array of education, age, and income levels, though on the whole they tend to be well-educated with annual incomes above the state average. The most commonly cited method of purchasing a new home is to purchase a lot from a builder and select one of several house plans offered by the builder—one in four homes was purchased by this method. On average, homeowners who purchased land and worked with an architect and/or builder to design and build the home have the most energy-efficient homes. Homeowners with annual incomes greater than $150,000 have, on average, the most efficient homes, while those with annual incomes less than $50,000 have the least efficient homes. Homeowners aged 65 and over tend both to have lower incomes and less efficient homes.

Over four-fifths of the homeowners discussed energy efficiency with their builder or sales agent. Most homeowners said that getting an energy-efficient home was relatively important in their decision to buy or build their home. However, homeowners who asked their builder or agent about energy efficiency, or who assigned a high importance rating to energy efficiency, did not necessarily get energy-efficient homes. Four out of five of the owners of the five least efficient homes asked their builder or sales agent about energy efficiency and assigned a high importance rating to getting an energy-efficient home. Survey findings indicate that homeowners are not very good at assessing the energy efficiency of their homes, although owners of custom homes tend to be better at this than owners of spec homes.

Nearly three-quarters (73%) of homeowners said that they had seen or heard of a newly constructed home being referred to as an ENERGY STAR Home. However, findings suggest making potential home buyers aware of ENERGY STAR homes is not enough to get them to act on that awareness when they look for a home or a builder to build a custom home. Fewer than one out of four homeowners who said they had seen or heard of a newly constructed home being referred to as an ENERGY STAR home said they asked their builder or sales agent about ENERGY STAR homes. See Section 6 Homeowner On-Site Survey.

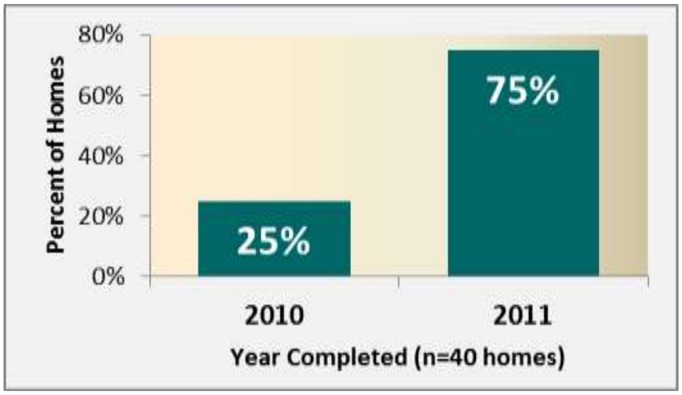
Remainder of the Report

Detailed information supporting the findings presented in this executive summary is provided in the body of the report. Appendix C Insulation Grades and Appendix D Building Practices—Examples from the Site Visits address how insulation installations were graded and provide examples of good and bad building practices observed during the site visits.

1 Introduction

Auditors conducted on-site audits at 40 recently completed single-family homes across Rhode Island that did not participate in the Rhode Island RNC Program. Figure 1-1 shows 25% of inspected homes were completed in 2010 and 75% in 2011.

Figure 1-1: Year Homes Completed



Homes were inspected from early August through early November of 2011 with several objectives in mind:

- Providing a baseline study of 40 recently completed single-family homes across Rhode Island that did not participate in the RI RNC Program and were permitted under 2009 IECC that can be used to update baseline home assumptions used in calculating energy savings for the Rhode Island Program
- Conducting a full HERS rating for each home using REM/Rate™ software
- Providing a comparison of 2011 baseline homes to single-family homes completed through the 2011 Program
- Using 2009 IECC compliance reports produced by REM/Rate to assess how the baseline homes would likely perform under different performance based compliance paths
- Assessing code compliance using the 2009 IECC checklist developed by Pacific Northwest National Laboratory (PNNL)

1.1 General Characteristics of Inspected Homes

The most popular style of the homes inspected is colonial (33% of inspected homes), followed by cape (18%), ranch (18%), and contemporary (15%). With the exception of two attached homes, all of the homes are detached single-family homes. All homes except for one are year-round primary residences. The smallest home inspected is 935 square feet and the largest is 5,244 square feet (Figure 1-2). The average conditioned floor area[5] for all homes is 2,245 square feet and the median is 1,974 square feet. The average custom home is 2,591 square feet and the average spec home is 2,058 square feet. The majority of homes (63%) are two stories; 33% are one to one and one-half stories and 5% are two and one-half to three stories. Figure 1-3 shows examples of the different size homes inspected.

Figure 1-2: Conditioned Floor Area

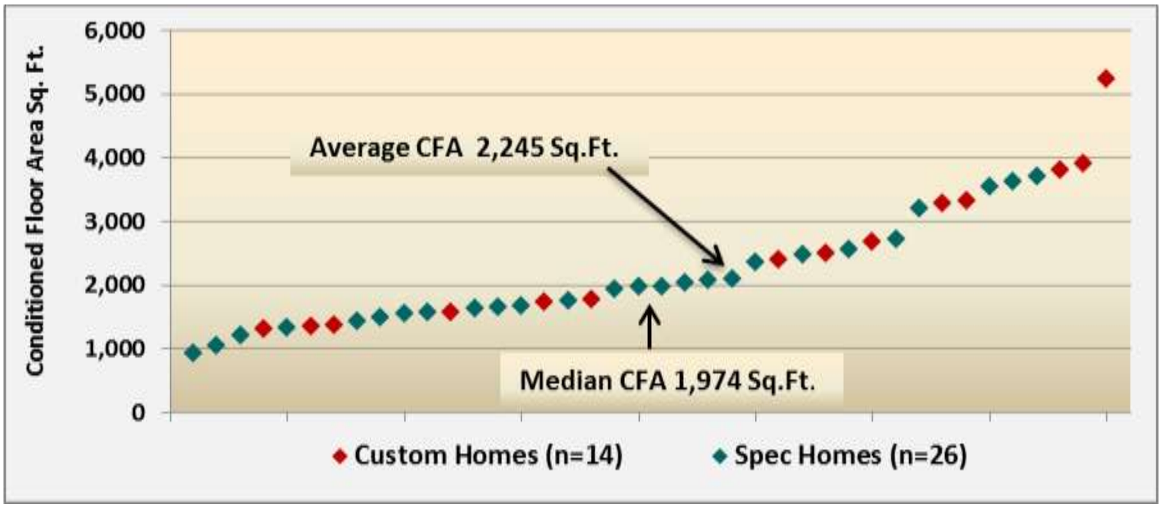


Figure 1-3: Examples of Inspected Homes

[5] RESNET definition of conditioned floor area (CFA): “CFA includes all finished space that is within the (insulated) conditioned space boundary (that is, within the insulated envelope), regardless of HVAC configuration. CFA includes unfinished spaces that are directly conditioned, that is, they have “fully ducted” intentional HVAC supply (or other intentional heat source). CFA does not include spaces such as insulated basements or attics that are unfinished, if there is no intentional HVAC supply, or minimal supply (inadequate to be considered directly conditioned space. CFA does not include heated garages.”
Source: http://www.resnet.us/standards/Floor_Area_Interpretation.pdf

1.1 On-Site Data Collection

An on-site data collection form that contained the inputs required to conduct a full HERS rating and complete the 2009 IECC checklist was developed. The data collection form was broken up into six primary sections that are detailed in Table 1-1. (See Appendix E Data Collection Form)

Table 1-1: Data Collection Form Inputs

General Information	Insulation/Shell Measures	Mechanical Equipment	Test Results	Lighting & Appliances	2009 IECC Checklist
• House type • Area of conditioned space • Volume of conditioned space • Primary heating fuel • Stories • Bedrooms • Thermostat type • Builder type • Own/Rent • Evaluation region	• Exterior walls • Ceilings • Frame floors • Rim/Band joists • Windows • Skylights • Doors • Slab Floors • Foundation walls • Mass walls • Sunspaces	• Heating equipment • Water heating equipment • Cooling equipment • Duct insulation • Renewables	• Blower door results • Duct blaster results	• CFL fixtures • Incandescent or Halogen fixtures • Fluorescent tube fixtures • LED fixtures • Ceiling Fans • Refrigerators • Dishwashers	• Yes/No checklist items that are not detailed within other sections of the form

One of the challenges of inspecting completed homes is that several building envelope components are not accessible or visible. Specifically, three components are difficult to verify in a post-occupancy inspection: slab insulation, exterior foundation wall insulation, and window efficiencies. Slab insulation is almost never visible once the slab has been poured. Similarly, if exterior foundation wall insulation does not extend above grade then it is very difficult to visually verify in a post-occupancy inspection. Finally, window U- and SHGC values are difficult to verify in occupied homes as most homeowners have removed the NFRC labels from the windows in their home and typically do not retain a copy. For all three measures auditors may be able to estimate the efficiency related characteristics based on building plans or discussions with homeowners, builders, or contractors.

Framing was relatively easy to determine based on the depth of the wall, which was determined either by looking at the width of a door frame or window, or by removing an electrical outlet cover and measuring the depth of the wall. Insulation levels and the quality of installation were harder to verify. Floor insulation type, R-value and installation grade were almost always verifiable, as insulated frame floors are rarely enclosed except when located between conditioned space and a garage or conditioned space and the outside. Wall insulation characteristics were frequently verifiable in the basement or attic knee walls, although the installation grade was sometimes reported as not observable because the walls were enclosed.

The default assumptions for the level of insulation were R-19 for 2x6 stud walls and R-11 for 2x4 stud walls; these are common insulation values for these size walls. The default assumption for the type of insulation was fiberglass batts if that was the type of insulation visible in other areas of the home. It is possible, using these assumptions, that the prevalence of fiberglass batts may be overestimated and the prevalence of other insulation types may be underestimated. However, given the verification of fiberglass batts in so many homes, this does seem to be a reasonable approach to estimating the insulation type in unobservable components. Throughout this report, the percentage of homes in which auditors were able to visually inspect insulation is reported.

In order to conduct a full HERS rating, auditors were required to assign an installation grade to each of the insulation components in the home. Per RESNET standards there are three insulation installation grades: Grade I, Grade II, and Grade III. In general, Grade I is a "perfect" installation, Grade II is a "pretty good" installation, and Grade III is a "sloppy" installation. (See Appendix C Insulation Grades for full definitions of Grade I, II and III installations and pictures of insulation installations observed in inspected homes.) If the insulation installation was visible, then auditors applied the RESNET definitions to determine the installation grade. When the insulation was not visible (e.g., an enclosed wall cavity) auditors used what was observed in other areas of the home to help estimate the installation grade for that particular component. For example, if exterior wall insulation was visible in an unconditioned walk-out basement and assigned a Grade II installation, then the above grade walls for that home were also assigned a Grade II installation.

Figure 1-4 shows a Grade I and a Grade III floor insulation installation.

Figure 1-4: Example of Grade I and Grade III Floor Insulation Installation

Wall insulation (where visible) was predominantly fiberglass batts and was typically assigned either a Grade II or Grade III installation. Frame floor insulation was also predominantly fiberglass batts and typically assigned a Grade III installation as the insulation was often out of contact with the subfloor. In general, Grade I applications were reserved for spray foam insulation and blown-in insulation (i.e., cellulose and fiberglass) in attics.

The full extent of duct sealing was often unobservable as insulation was covering large portions of ductwork, preventing visual verification of duct sealing in many places. It was also difficult to verify that none of the building cavities were being used as supply ducts. In all applicable cases, auditors verified that basement floor joists were not being used as supply cavities. That said, in many cases it was difficult to confirm, without a reasonable doubt, that none of the wall cavities were being used as supply ducts.

2 Sampling Methodology

The sampling methodology involved developing a sample of new homes from utility new residential permanent service requests and additional information collected from the city and town building departments about new homes that had been permitted under IECC 2009. Homes for the on-site inspections were selected based on their location and whether they were spec or custom built.

2.1 Sampling Plan

The sampling plan, shown in Table 2-1, was based on the number of building permits for homes in single unit residential buildings issued in each Rhode Island county in 2010.

Table 2-1: Sampling Plan

County	One Unit Building Permits	Percent of State One Unit Building Permits	Targeted On-Site Inspections
Bristol	38	5%	2
Kent	92	13%	5
Newport	91	13%	5
Providence	272	37%	15
Washington	234	32%	13
Total	**727**	**100%**	**40**

In addition to the specified number of on-site inspections by county, the study attempted to recruit as many spec homes as possible, with a set limit of no more than 20 custom homes. The goal was to come as close as possible to the 90% to 10% spec/custom mix in the Rhode Island RNC Program, even though it was apparent that there were not enough spec homes built and occupied under IECC 2009 in the timeframe allowed for the on-sites. The reason for getting as many spec homes as possible was to provide a valid comparison of 2011 baseline study homes to single-family homes completed through the 2011 Program, which were overwhelmingly spec built homes. Spec and custom built homes were defined according to the homeowner's response to the following screening question:

How did you purchase your home?

1. Purchased land and worked with an architect and/or builder to build the home
2. Had a house plan and a lot and hired a contractor/builder to build the home
3. Purchased a lot from a builder selected one of several house plans offered by the builder and selected from various available upgrade options
4. Purchased a home that was under construction and selected from various available upgrade options

5. Purchased a finished home
6. I am the owner and builder

Homes were classified as custom built if the homeowner chose responses 1, 2, or 6; if the home owner chose responses 3, 4, or 5, the home was classified as spec built.

There was also a goal to perform no more than two on-site inspections in each community; the reasoning is that new residential construction in each city and town would come under the same building inspection department and may thus have similar rates of code compliance. Because single unit new construction under IECC 2009 was concentrated in particular communities, these limits were eventually raised to four in Warwick, three in Tiverton, four in Lincoln, three in Smithfield, five in South Kingstown, five in Westerly, and three in all other cities and towns.

2.2 Sample Development

The sample of homes for the on-site inspections was initially developed from new residential permanent service requests collected by National Grid. New permanent service requests have been used to identify newly constructed homes for various baseline studies and new home buyer surveys. However, the tight timeframe for completing inspections of homes permitted under IECC 2009 necessitated repeated contacts with various building departments to ascertain that the homes identified by the new service requests had indeed been permitted under IECC 2009 and to identify additional homes that had been recently permitted under the new code.

The data from the permanent new service requests received by National Grid from July 1, 2010 through approximately the first three months of 2011 were cleaned to remove addresses where:

- The home had participated in the Rhode Island Program.
- The housing unit was obviously not a single-family detached or attached home.
- There was only the builder's name on the utility record.

After the initial cleaning, the addresses were checked through the local building departments to ensure that the home had been permitted after the date when IECC 2009 would have been compulsory; the checks with the building departments also meant that new service requests that did not involve new home construction, such as those involving additions to existing homes or major renovations, could be screened out at this stage. Additional addresses that had been recently permitted under the new code, completed construction, and, in the case of spec homes, were no longer owned by the builders, were collected from the building departments. In total, information was obtained from 38 out of the 40 municipal building departments in Rhode Island.[6] A total of 268 addresses considered possible candidates for the 40 on-sites were thus identified.

[6] Including 11 building departments that were contacted but reported that no homes had been built under IECC 2009.

2.3 Sample Selection

Sample selection involved pre-recruitment of both the homeowners identified through the utility permanent new service requests and building department records of homes permitted under IECC 2009.

2.3.1 Pre-Recruitment

Each homeowner at the 268 addresses identified was mailed a letter, with the National Grid logo, explaining the purpose of the study, what the on-site inspections would be like, and the incentives of $150 to $200 offered for participation. Where addresses identified through the building departments did not have phone numbers, homeowners were mailed a postcard they could return with a phone number along with the letter explaining the purpose of the study.

2.3.2 Sample Disposition

The sampling plan targeting a certain number of on-sites in each county along with the goal of a limited number of inspections per community and the spec/custom mix meant that some of the pre-recruited sample could not be used. Of the 268 names, 151 were considered not eligible because 1) the quota of inspections in a particular county was reached; 2) a certain number of inspections had already been scheduled in their city or town; or 3) a limit was being placed on the homes thought to be custom that were recruited. This meant a valid sample of 117 homes. Table 2-2 summarizes the disposition of the sample.

Table 2-2: Sample Disposition

Sample Description	Number	Percent
Sample	**268**	
Sample considered not eligible	151	
Valid Sample	**117**	
Completed on-site inspections	40	34%
Refusals	19	16%
Not reached	58	50%

It is important to note that the overwhelming majority of the valid sample not reached consists of messages left for homeowners that had no follow-up because the desired number of on-site inspections was reached. Of the homeowners who were reached, there were more than twice as many acceptances (40) than refusals (19).

2.4 Completed On-Site Inspections

As Table 2-3 shows, the completed on-site inspections followed the sampling plan shown in Table 2-1 as closely as possible given the available number of homes permitted under IECC 2009 and achieved a spec/custom mix of 65% to 35%.

Table 2-3: Completed On-Site Inspections

County	Total On-Site Inspections	Spec Built	Custom Built
Bristol	1	0	1
Kent	6	4	2
Newport	10	7	3
Providence	12	8	4
Washington	11	7	4
Total	**40**	**26**	**14**

Moreover, the inspections took place in 21 cities and towns across Rhode Island; there was only one inspection done in 12 communities, two inspections done in each of two communities, three inspections done in each of four communities, and four inspections done in each of three communities. The 21 communities covered are shown in Figure 2-1.

Figure 2-1: On-Site Inspections

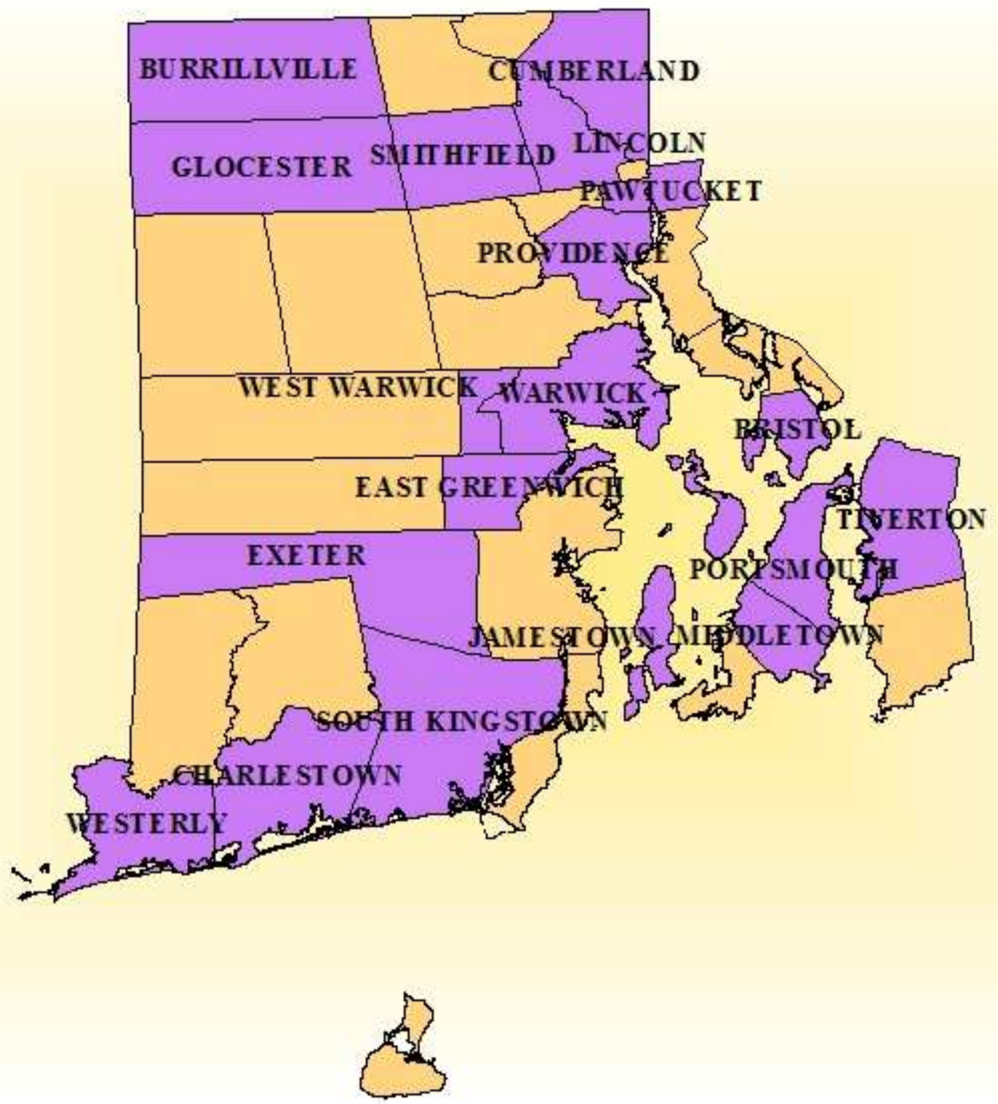


Table 2-4 presents summary economic characteristics by county. More than one-half of on-sites (55%) were conducted in counties where the median value of owner-occupied housing units is above the statewide median; 70% of on-sites were conducted in counties were the median household income is above the statewide median.

Table 2-4: Economic Characteristics by County

County	Completed On-Site Inspections	Median Value of Owner-Occupied Units*	Median Household Income*
Bristol	1	$345,432	$65,237
Kent	6	$240,900	$58,907
Newport	10	$375,700	$64,250
Providence	12	$242,400	$47,887
Washington	11	$341,400	$69,083
Total Rhode Island	**40**	**$283,700**	**$53,243**

*http://quickfacts.census.gov/qfd/states/09/09001.html; median home values and income are for the years 2006 through 2010

There is considerable variation in economic characteristics among the cities and towns within each county, so Table 2-5 examines the median housing values and incomes in the communities with on-sites. At a community level, there were considerably more on-sites in communities with housing values above the statewide median and in communities with incomes above the statewide median.

Table 2-5: Economic Characteristics by Community

	Median Value of Owner-Occupied Units*	Median Household Income*
On-Sites in Communities Above State Median	77%	70%
On-Sites in Communities Below State Median	23%	30%

*http://www.city-data.com/; data are for 2009.

2.5 Weighting

While a great effort was made to recruit as many spec built homes as possible for the on-sites, there was a higher portion of spec built homes that participated in the RI RNC Program (90%) than spec built homes that participated in the on-sites (65%). Thus, in order to reflect the mix in the Rhode Island ENERGY STAR Program, the data are weighted by 90% for spec built homes and 10% for custom homes.

The tables in this report generally show the unweighted data from all 40 homes inspected for the 2011 baseline, the unweighted data from the spec built homes inspected, the unweighted data from the custom homes inspected and the weighted average of spec and custom homes. Statistically significant differences at the 90% confidence level between spec and custom homes are noted in the appropriate tables.

2.6 Sampling Error

In developing the on-site sample design, the evaluation team drew from experience in similar studies to estimate a coefficient of variation (CV) and a sample size that would provide a precision of ± 10% at the 90% confidence level. Assuming a coefficient of variation of 0.49, based on a Vermont residential new construction baseline study conducted in 2008[7], the team estimated that a sample size of 59 homes would be adequate to produce a final precision of ± 10% at the 90% confidence level; assuming a lower coefficient of variation of 0.37, based on a Massachusetts residential new construction baseline study conducted in 2005[8], would reduce the estimated sample size to produce a final precision of ± 10% at the 90% confidence level to 35 homes.

As a result of this study the evaluation team is able to utilize actual coefficients of variation to estimate the final precision levels of key home characteristics. The coefficient of variation is of central importance to determining the final precision levels. A primary objective of this study is to document the existing building and equipment status of new single-family homes by feature. Some features are far more variable than others. In this study, duct leakage and air infiltration are the most variable, and HVAC system efficiencies the least variable. No single building component is a reliable indicator of a building’s overall efficiency. An advantage of conducting HERS ratings on all homes is that we have a measure of a home’s overall energy efficiency that looks at a home as a system and how various individual components of the home work together.

[7] Vermont Residential New Construction Baseline Study Analysis of On-site Audits, Submitted to Vermont Department of Public Service by Nexus Market Research, Inc., RLW Analytics, Inc. and Dorothy Conant. July 2009.

[8] Massachusetts ENERGY STAR Homes 2005 Baseline Study Part I: Inspection Data Analysis, Submitted to Joint Management committee by Nexus Market Research and Dorothy Conant. May 2006.

Table 2-6 shows the coefficients of variation and relative precisions at the 90% confidence level for several key building components and measurements that influence a home's energy efficiency. Based on these coefficients of variation, relative precision ranges from ± 0.9% for all central air conditioning SEER to ± 19.2% for duct leakage. The HERS index, which is the one measurement that addresses multiple building components, has a coefficient of variation of 0.15 and a good relative precision of ± 3.8% at the 90% confidence level.

Table 2-6: Coefficients of Variation and Relative Precision for Key Residential Construction Measurements

Parameter	Sample Size	Coefficient of Variation	Relative Precision
Central Air Conditioning SEER	39	0.04	±0.9%
All Fossil-Fuel Fired Heating System AFUE	43	0.06	±1.4%
HERS Index	40	0.15	±3.8%
Conditioned/Ambient Wall Insulation R-Value	40	0.19	±4.7%
Flat Ceiling Insulation R-Value	35	0.19	±5.1%
Cathedral Ceiling Insulation R-Value	19	0.18	±6.5%
Air Infiltration—Air Changes per Hour at 50 Pascals	38	0.35	±9.0%
Duct Leakage—CFM25/100 Sq. Ft.	22	0.56	±19.2%

3 Preliminary User Defined Reference Home (UDRH) Inputs

The 2011 Baseline UDRH inputs are preliminary estimates based on study findings weighted to reflect the mix of single-family spec and custom housing in the 2011 Program. This section presents detailed tables showing the data used to develop UDRH inputs. Several of the rows in the tables are data that show study results in more detail than used for UDRH inputs, for example more detailed heating system categories—these rows are marked “For Reference Only.” These For Reference Only rows are included to provide supporting information that the Program Administrator may find useful when developing final UDRH inputs. Because of small baseline sample sizes in Rhode Island for some types of heating systems, water heating systems, foundation walls and slabs, data are presented for combined Rhode Island and Massachusetts baseline samples as well as for just the Rhode Island sample. The Program Administrator will review these preliminary UDRH estimates and develop a final set of UDRH inputs.

HEATING UDRH INPUTS		Weighted Sample Results (90% Spec 10% Custom)							
Current Rhode Island	UDRH Inputs	All Systems (n)	Weighted Average AFUE	All Homes Average AFUE (Raw Data)	Systems in Spec Homes (n)	Spec Home Average AFUE	Systems in Custom Homes (n)	Custom Home Average AFUE	Spec/ Custom Difference
Gas Fuel Fired Air Distribution (Furnaces and Hydro-Air)	89.2 AFUE	26	92.2	92.30	18	92.14	8	92.73	Not Significant
Gas Fuel Fired Hydronic Distribution (Hot Water Boilers)	81.7 AFUE	10	88.7	90.52	6	88.08	4	94.18	Significant
All Gas fuel Fired Systems	For Reference Only	36	91.3	91.82	24	91.12	12	93.21	Not Significant
Oil Fuel Fired Air Distribution (Furnaces and Hydro-Air)	83.9 AFUE	2	81.6	84.00	1	81.00	1	87.00	n/a
Oil Fuel Fired Hydronic Distribution (Hot Water Boilers)	84.4 AFUE	4	86.0	85.99	3	85.99	1	86.00	n/a
All Oil fuel Fired Systems	For Reference Only	6	84.9	85.33	4	84.74	2	86.50	n/a
RI & MA DATA COMBINED: WEIGHTED 90% Spec 10% Custom									
Gas Fuel Fired Air Distribution (Furnaces and Hydro-Air)	For Reference Only	126	92.1	92.09	99	92.06	27	92.20	Not Significant
Gas Fuel Fired Hydronic Distribution (Hot Water Boilers)	For Reference Only	17	86.8	89.02	10	86.09	7	93.21	Significant
All Gas fuel Fired Systems	For Reference Only	143	91.6	91.72	109	91.51	34	92.41	Not Significant
Oil Fuel Fired Air Distribution (Furnaces and Hydro-Air)	For Reference Only	12	83.5	84.04	9	83.11	3	86.83	Significant
Oil Fuel Fired Hydronic Distribution (Hot Water Boilers)	For Reference Only	7	85.3	85.37	6	85.26	1	86.00	n/a
All Oil fuel Fired Systems	For Reference Only	19	84.2	84.53	15	83.97	4	86.63	Significant
Heating System Location	**Unconditioned Space**								
Boilers in Conditioned Space	For Reference Only	20	16%*of Systems	15% of Systems	12	17% of Systems	8	13%	Not Significant
Furnaces in Conditioned Space	For Reference Only	22	31%* of Systems	32% of Systems	16	31% of Systems	6	33%	Not Significant
Boilers and Furnaces in Conditioned space	For Reference Only	42	25%* of Systems	24% of Systems	28	25% of Systems	14	21%	Not Significant
Individual Heating System Types									
Fuel Fired Air Distribution (natural gas)	For Reference Only	14	93.0	92.5	9	93.2	5	91.4	Not Significant
Fuel Fired Hydronic Distribution (natural gas)	For Reference Only	5	92.5	93.0	3	92.3	2	94.10	n/a
Fuel Fired Air Distribution (propane)	For Reference Only	12	91.5	92.1	9	91.1	3	95.00	Significant
Fuel Fired Hydronic Distribution (propane)	For Reference Only	5	84.9	88.0	3	83.8	2	94.25	n/a
Combined appliance (natural gas)	For Reference Only	1	91.0	91.0	1	91.0	0	n/a	n/a
Combined appliance (propane)	For Reference Only	No Baseline Homes							

HEATING UDRH INPUTS		Weighted Sample Results (90% Spec 10% Custom)							
Current Rhode Island	UDRH Inputs	All Systems (n)	Weighted Average AFUE	All Homes Average AFUE (Raw Data)	Systems in Spec Homes (n)	Spec Home Average AFUE	Systems in Custom Homes (n)	Custom Home Average AFUE	Spec/ Custom Difference
Individual Heating System Types (continued)									
Combined appliance (oil)	For Reference Only	**No Baseline Homes**							
Air Source Heat Pump	For Reference Only	**No Baseline Homes**							
Ground Source Heat Pump	For Reference Only	**1**	**14.2 HSPF (4.15 COP)**	**14.2 HSPF (4.15 COP)**	1	14.2 HSPF (4.15 COP)	0	n/a	n/a
Dual Fuel Heat Pump	For Reference Only	**No Baseline Homes**							
All Gas Furnaces Natural Gas & Propane	For Reference Only	**22**	**92.6**	**92.8**	16	92.5	6	93.6	Not Significant
Natural Gas Furnaces	For Reference Only	**10**	**94.0**	**93.6**	7	94.2	3	92.1	**Significant**
Propane Furnaces	For Reference Only	**12**	**91.5**	**92.1**	9	91.1	3	95.0	**Significant**
All Oil Furnaces	For Reference Only	**No Baseline Homes**							
Gas Boilers Nat. Gas & Propane	For Reference Only	**14**	**88.9**	**90.4**	8	88.5	6	92.87	**Significant**
Natural Gas Boilers	For Reference Only	**9**	**91.3**	**91.7**	5	91.2	4	92.18	Not Significant
Propane Boilers	For Reference Only	**5**	**84.9**	**88.0**	3	83.8	2	94.25	n/a
Oil Boilers	For Reference Only	**6**	**84.9**	**85.3**	4	84.7	2	86.50	n/a

COOLING UDRH INPUTS		Weighted Sample Results (90% Spec 10% Custom)							
Current Rhode Island UDRH Inputs		All Systems or Homes (n)	Weighted Average	All Homes Average (Raw Data)	Systems in Spec Homes (n)	Spec Home Average	Systems in Custom Homes (n)	Custom Home Average	Attached/ Detached Difference
Air Conditioner SEER	13 SEER	40	13.1 SEER	13.4 SEER	25	13.1 SEER	15	13.9 SEER	Significant
Square Feet of Conditioned Space per Ton	For Reference Only	27 Homes	625 Sq. Ft	645 Sq. Ft.	18	616 Sq. Ft.	9	703	Not Significant
Located in Conditioned Space	For Reference Only	41	23% of A/C Units	22% of A/C Units	25	24% of A/C Units	16	19%	Not Significant
Ground Source Heat Pump	For Reference Only	1	20.75 EER	20.75 EER	0	n/a	1	20.75 EER	n/a
Ductless Mini Split*	For Reference Only	1	19.0 SEER	19.0 SEER	0	n/a	1	19	n/a

*Ductless Mini Split cools only one room. It is not included in square feet per ton data, which includes only homes with central air conditioning for the entire home. It is included in the Air Conditioner Unit SEER data.

WATER HEATING UDRH INPUTS		Weighted Sample Results (90% Spec 10% Custom)							
Current Rhode Island UDRH Inputs		All Systems (n)	Weighted Average EF	All Homes Average EF (Raw Data)	Systems in Spec Homes (n)	Average EF	Systems in Custom Homes (n)	Average EF	Spec/Custom Difference
Gas Conventional	0.58 EF	8	0.63	0.63	7	0.63	1	0.65	n/a
Gas Integrated	0.75 EF	8	0.80	0.82	4	0.80	4	0.84	Not Significant
Oil Conventional	0.61 EF	No Baseline Homes							
Oil Integrated	0.69 EF	4	0.78	0.78	2	0.77	2	0.80	n/a
Electric Resistance	0.86 EF	6	0.91	0.91	5	0.91	1	0.90	n/a
RI & MA DATA COMBINED: WEIGHTED 90% Spec 10% Custom									
Gas Conventional	For Reference Only	60	0.63	0.63	52	0.63	8	0.64	Not Significant
Gas Integrated	For Reference Only	19	0.81	0.84	6	0.81	13	0.85	Significant
Oil Conventional	For Reference Only	No Baseline Homes							
Oil Integrated	For Reference Only	10	0.78	0.79	6	0.78	4	0.80	Not Significant
Electric Resistance	For Reference Only	26	0.90	0.90	23	0.90	3	0.89	Not Significant
Gas Instantaneous	0.62 EF	23	0.84	0.85	12	0.84	11	0.86	Not Significant
Weighted Average all Natural Gas and Propane Conventional and Instantaneous (weighting based on percentages of conventional and instantaneous systems) For Reference Only		83		0.69					
all Natural Gas and Propane Conventional and Instantaneous		83	0.68	0.69	64	0.67	19	0.77	Significant
Water Heater Location	**Unconditioned Space**								
Instant (Boiler) Percent in Conditioned Space	For Reference Only	11	25%	45%	5	20%	6	67%	Not Significant
Integrated (with Tank & Tankless Coil) Percent In Conditioned Space	For Reference Only	16	21%	19%	9	22%	7	14%	Not Significant
Storage Percent in Conditioned Space	For Reference Only	14	33%	36%	12	25%	2	100%	Significant
Total Percent in Conditioned Space	For Reference Only	41	25%	32%	26	23%	15	47%	Not Significant
Conventional (Natural Gas)	For Reference Only	6	0.62	0.63	5	0.62	1	0.65	n/a
Conventional (Propane)	For Reference Only	2	0.65	0.65	2	0.65	0	n/a	n/a
Integrated (Natural Gas)	For Reference Only	5	0.83	0.83	2	0.82	3	0.84	n/a
Integrated (Propane)	For Reference Only	3	0.78	0.78	2	0.77	1	0.85	n/a

WATER HEATING UDRH INPUTS		Weighted Sample Results (90% Spec 10% Custom)							
Current Rhode Island UDRH Inputs		All Systems (n)	Weighted Average EF	All Homes Average EF (Raw Data)	Systems in Spec Homes (n)	Average EF	Systems in Custom Homes (n)	Average EF	Spec/Custom Difference
Instantaneous Gas	For Reference Only	**11**	**0.85**	**0.87**	5	0.84	6	0.89	**Significant**
Instantaneous (Natural Gas)	For Reference Only	**5**	**0.86**	**0.86**	3	0.85	2	0.88	n/a
Instantaneous (Propane)	For Reference Only	**6**	**0.83**	**0.88**	2	0.83	4	0.90	n/a
Tankless Coil	For Reference Only	**4**	**0.48**	**0.48**	3	0.48	1	0.45	n/a
All Natural Gas and Propane Conventional and Instantaneous. For Reference Only		**19**	**0.73**	**0.77**	12	0.72	7	0.86	**Significant**
Weighted Average all Natural Gas and Propane Conventional and Instantaneous (weighting based on percentages of conventional and instantaneous systems) For Reference Only		**19**		**0.77**					

Wall UDRH INPUTS		Weighted Sample Results (90% Spec 10% Custom)							
Current Rhode Island UDRH Inputs		All Homes (n)	Weighted Average Uo or R-value	All Homes Average Uo or R-value (Raw Data)	Spec Homes (n)	Spec Home Average Uo or R-value	Custom Homes (n)	Custom Home Average Uo or R-value	Spec/Custom Difference
Above Grade Wall (Conditioned/Ambient)	Uo= .065	40	0.073	0.071	26	0.074	14	0.066	Significant
Above Grade Wall (Conditioned/Ambient)	R-20 For Reference Only	40	17.7	18.3	26	17.5	14	19.6	Significant
Conditioned/Garage Wall U-value	For Reference Only	26	0.077	0.075	19	0.078	7	0.069	Not Significant
Conditioned/Garage Wall R-value	For Reference Only	26	17.0	17.3	19	16.7	7	19.0	Not Significant
Conditioned/Attic Wall U-value	For Reference Only	10	0.081	0.087	6	0.080	4	0.097	Significant
Conditioned/Attic Wall R-value	For Reference Only	10	16.7	15.6	6	17.0	4	13.5	Not Significant

Floor UDRH INPUTS		Weighted Sample Results (90% Spec 10% Custom)							
Current Rhode Island UDRH Inputs		All Homes (n)	Weighted Average Uo or R-value	All Homes Average Uo or R-value (Raw Data)	Spec Homes (n)	Spec Home Average Uo or R-value	Custom Homes (n)	Custom Home Average Uo or R-value	Spec/Custom Difference
Frame Floor over Unconditioned Basement	Uo= .04	26	0.119	0.111	19*	0.123	7	0.079	Not Significant
Frame Floor over Unconditioned Basement	R-30 For Reference Only	27	17.6	18.3	20	17.2	7	21.7	Not Significant
Frame Floor over Outside Air U-value	For Reference Only	10	0.085	0.069	6	0.09	4	0.038	Not Significant
Frame Floor over Outside Air R-value	For Reference Only	10	23.8	27.5	6	22.5	4	35.0	Significant
Frame Floor over Garage U-value	For Reference Only	13	0.054	0.069	8	0.049	5	0.100	Not Significant
Frame Floor over Garage R-value	For Reference Only	13	25.6	23.9	8	26.1	5	20.4	Not Significant

Ceiling UDRH INPUTS		Weighted Sample Results (90% Spec 10% Custom)							
Current Rhode Island UDRH Inputs		All Homes (n)	Weighted Average Uo or R-value	All Homes Average Uo or R-value (Raw Data)	Spec Homes (n)	Spec Home Average Uo or R-value	Custom Homes (n)	Custom Home Average Uo or R-value	Spec/Custom Difference
Attic	Uo= .058	35	**0.051**	**0.051**	24	0.051	11	0.051	Not Significant
Attic	R-31 For Reference Only	35	**34.6**	**34.5**	24	34.6	11	34.2	Not Significant
Vaulted	Uo= .057	19	**0.044**	**0.043**	9	0.045	10	0.041	Not Significant
Vaulted	R-29.6 For Reference Only	19	**32.8**	**33.0**	9	32.8	10	33.2	Not Significant

* There is no U-value for one basement because it was treated as conditioned volume and was not modeled in REM/Rate. This floor had R-38 insulation.

Infiltration UDRH INPUTS		Weighted Sample Results (90% Spec 10% Custom)							
Current Rhode Island UDRH Input	2011 Baseline Home Category	All Homes (n)	Weighted Average ACH50	All Homes Average ACH50 (Raw Data)	Spec Homes (n)	Spec Home Average ACH50	Custom Homes (n)	Custom Home Average ACH50	Spec/Custom Difference
ACH50 6.72	All Baseline Homes	40	**5.71**	**5.63**	26	5.74	14	5.44	Not Significant
	Only baseline homes with basements that are finished and conditioned space and homes with fully unconditioned basements that are not conditioned floor area (CFA) and were not included in the testing	38	**5.96**	**5.81**	24	6.02	14	5.44	Not Significant
	Only homes where the basement was included in the testing (Conditioned Volume) but the basement area was not conditioned floor area	2	**2.34**	**2.34**	2	2.34	0	n/a	n/a

DUCT LEAKAGE UDRH INPUTS			Weighted Sample Results (90% Spec 10% Custom)							
Current Rhode Island UDRH Input		2011 Baseline Home Category	All Systems (n)	Weighted Average CFM25/ 100 Ft²	All Homes Average CFM25/ 100 Ft² (Raw Data)	Spec Homes (n)	Spec Home Average CFM25/ 100 Ft²	Custom Homes (n)	Custom Home Average CFM25/ 100 Ft²	Spec/Custom Difference
Duct Leakage CFM25/100 Ft²	14	All Tests at All Homes with Ducts	24	**18.1**	**17.5**	17	18.4	7	15.4	Not Significant
		No Conditioned Volume/ Not CFA Basements	22	**20.0**	**18.9**	15	20.5	7	15.4	Not Significant
		Conditioned Volume/ Not CFA Basements	2	**2.1**	**2.1**	2	2.1	0	n/a	n/a

WINDOW UDRH INPUTS		Weighted Sample Results (90% Spec 10% Custom)							
Current Rhode Island UDRH Inputs		All Homes (n)	Weighted Average U- or SHGC Value	All Homes Average U- or SHGC Value	Spec Homes (n)	Spec Home Average U- or SHGC Value	Custom Homes (n)	Custom Home Average U- or SHGC Value	Spec/Custom Difference
Window Uo (baseline data)	Uo= 0.35	5	0.32	**0.31**	2	0.33	3	0.30	n/a
Window Uo (baseline data with defaults)	Uo= 0.35	40	0.34	**0.34**	26	0.34	14	0.33	Not Significant
Window SHGC (baseline data)	Uo= 0.35	4	0.31	**0.35**	2	0.30	2	0.40	n/a

Documented U-value and SHGC information was available for 1 home where the original NFRC (National Fenestration Rating Council) sticker was visible. Auditors had access to the U-value and/or SHGC, or to information with which they could estimate the U-value and/or SHGC (such as the window manufacturer and series listed in a home's plans) for an additional 4 homes. Based on feedback from several window manufacturers and lumber stores, the default value of 0.34 is used.

FOUNDATION WALL UDRH INPUTS		Weighted Sample Results (90% Spec 10% Custom)							
Current Rhode Island UDRH Inputs		All Homes (n)	Weighted Average R-Value	All Homes Average R-value (Raw Data)	Spec Homes (n)	Spec Home Average R-Value	Custom Homes (n)	Custom Home Average R-Value	Spec/Custom Difference
Foundation Wall Insulation in Conditioned Basements R-Value	R-13	4	**18.55**	**16.75**	2	19.00	2	14.50	n/a
Foundation Wall Insulation in unconditioned Basements R-Value	R-3.1	33	**1.06**	**0.82**	23	1.17	10	0.00	Not Significant
RI & MA DATA COMBINED: WEIGHTED 90% Spec 10% Custom									
Foundation Wall Insulation in Conditioned Basements R-Value For Reference Only		24	**13.36**	13.38	13	13.35	11	13.41	Not Significant
Foundation Wall Insulation in unconditioned Basements R-Value For Reference Only		112	**0.30**	0.26	88	0.33	24	0.00	Not Significant

SLAB UDRH INPUTS		Weighted Sample Results (90% Spec 10% Custom)								
Current Rhode Island UDRH Inputs		All Homes (n)	Weighted Average R-Value	All Homes Average R-value (Raw Data)	Spec Homes (n)	Spec Home Average R-Value	Custom Homes (n)	Custom Home Average R-Value	Spec/Custom Difference
Slab R-Value (All baseline homes with data)	For Reference Only	6	0.50	3.33	2	0.00	4	5.00	n/a
On-Grade Slab Non-Radiant Heat R-Value (All baseline homes with data)	R-0.2	3	0.50	3.33	1	0.00	2	5.00	n/a
Below-Grade Slab Non-Radiant Heat R-Value (All baseline homes with data)	R-0	4	0.50	2.50	2	0.00	2	5.00	n/a
On-Grade Slab-Radiant Heat R-Value (All baseline homes with data)	R-10.7	1	10.00 (unweighted)	10.00	0	n/a	1	10.00*	n/a
Below-Grade Slab-Radiant Heat R-Value (All baseline homes with data)	R-0	0	n/a	n/a	0	n/a	0	n/a	n/a
RI & MA DATA COMBINED: WEIGHTED 90% Spec 10% Custom									
Slab R-Value (All baseline homes with data) For Reference Only		19	0.31	2.11	6	0.00	13	3.08	Significant
Slab Non-Radiant Heat R-Value (All baseline homes with data) For Reference Only		18	0.25	1.67	6	0.00	12	2.50	Significant
Slab-Radiant Heat R-Value (All baseline homes with data) For Reference Only		1	10.00 (unweighted)	10.00	0	n/a	1	10.00	n/a

* The home with R-10 insulated radiant slab floor also has R-15 insulation on the slab perimeter.

DUCT INSULATION UDRH INPUTS		Weighted Sample Results (90% Spec 10% Custom)							
Current Rhode Island UDRH Inputs		All Homes (n)	Weighted Average R-Value	All Homes Average R-value (Raw Data)	Spec Homes (n)	Spec Home Average R-Value	Custom Homes (n)	Custom Home Average R-Value	Spec/Custom Difference
Duct Insulation--all in unconditioned space R-Value	R-4.68	24	**6.62**	**6.55**	17	6.66	7	6.27	Not Significant
Duct Insulation--Supply in unconditioned basements R-Value	R-5.29	16	**6.45**	**6.54**	12	6.36	4	7.30	Not Significant
Duct Insulation--Supply in attics R-Value	R-7.46	16	**7.57**	**7.39**	11	7.65	5	6.86	**Significant**
Duct Insulation--Return in unconditioned basements R-Value	R-4.42	16	**5.18**	**5.24**	12	5.13	4	5.63	Not Significant
Duct Insulation--Return in attics R-Value	R-5.24	15	**7.52**	**7.11**	10	7.71	5	5.78	Not Significant

4 Comparison to 2011 Program Single-Family Homes

This section compares selected building characteristics in 2011 baseline homes and single-family homes completed through the 2011 Program; the 2011 Program homes exclude those that failed to meet Program requirements. Comparisons address:

- Conditioned/Ambient Walls
- Flat Ceilings
- Cathedral Ceilings
- Conditioned/Basement Floors
- Foundation Walls
- Duct Insulation
- Duct Leakage
- Air Infiltration
- HERS Indices

For conditioned/ambient walls, ceilings and floors both observed insulation R-values and calculated U-values are addressed. U-values are the overall heat transfer coefficient for the entire wall, floor or ceiling assembly, not just the insulation. The lower the U-value is, the more energy efficient the assembly. U-values calculated using REM/Rate software account for the R-value of framing members, the R-value of other components such as air barriers and drywall, the R-value of the insulation, and the quality of the insulation installation. If insulation is compressed, or there are gaps, the energy efficiency of the assembly is lower and the U-value is higher.

The following differences between 2011 baseline and Program homes are statistically significant at the 90% confidence level:

- The average flat ceiling is more energy efficient (lower U-value) in Program homes.
- The average floor over an unconditioned basement is more energy efficient (higher insulation R-value and lower U-value) in Program homes.
- The average R-value of attic supply duct insulation is higher in Program homes.
- Average duct leakage and air infiltration are lower (more energy efficient) in Program homes.
- Program homes have a lower (better) average HERS index.

In Table 4-1, the first column of data is the average over all inspected homes; the second column is the average over all single-family homes that were completed through the 2011 Program—this excludes homes that failed to meet Program requirements; the third column is the current UDRH input; and the fourth column is the raw data for spec and custom baseline homes weighted to reflect the mix of single-family spec and custom homes in the 2011 Program, which is typically also the preliminary estimated UDRH input.

Table 4-1: Comparison of 2011 Baseline and 2011 Program Homes

Baseline Compared to 2011 Program Homes	RI Baseline 2011 Raw Data	RI 2011 Program	Current UDRH Input	Baseline Weighted & Preliminary UDRH Input
Average Conditioned/Ambient Wall Insulation R-value	18.3	18.1	**20**	**17.7**
Average Conditioned/Ambient Wall Insulation U-value	0.071	0.068	**0.065**	**0.073**
Average Flat Ceiling Insulation R-value	34.5	35.0	31	**34.6**
Average Flat Ceiling Insulation U-value	**0.051***	**0.031***	0.058	**0.051**
Average Cathedral Ceiling Insulation R-value	33.0	33.2	29.6	**32.8**
Average Cathedral Ceiling Insulation U-value	0.043	0.036	0.057	**0.044**
Average Conditioned/Basement Floor Insulation R-value	**18.3***	**25.9***	30	**17.6**
Average Conditioned/Basement Floor Insulation U-value	**0.111***	**0.047***	0.04	**0.119**
Foundation Wall Insulation - Conditioned Basements R-value	16.8	14.2	13	**18.6**
Foundation Wall Insulation - Unconditioned Basements R-value	0.8	0.8	3.1	**1.1**
Duct Insulation - Attic Supply R-value	**7.3***	**7.8***	7.46	**7.6**
Duct Insulation - All other Unconditioned Spaces	6.5	6.3	4.68	**6.6**
Average Duct Leakage--CFM25/100 ft2	**18.9***	**4.3***	14	**20.0**
Air Infiltration—Average ACH50	**5.81***	**3.93***	6.72	**5.96**
Average HERS Index	**85***	**66***	n/a	**87**

*Significantly different at the 90% confidence level.

Conditioned/Ambient Walls

The unweighted average R-value of insulation in conditioned/ambient walls in 2011 baseline homes (R-18.3) is slightly higher than in 2011 Program homes (R-18.1). This is not surprising since all of the 2011 baseline homes were permitted under 2009 IECC, when the prescriptive requirement for conditioned/ambient wall insulation is R-20, and many of the 2011 Program homes were permitted under 2006 IECC, when the prescriptive requirement was R-19. However, the weighted average R-value of R-17.7 for 2011 baseline homes (weighted to reflect the mix of single-family spec and custom housing in the 2011 Program) is lower than the 2011 Program average of R-18.1. Looking at U-values, the average unweighted (U-0.071) and weighted (U-0.073) values for 2011 baseline homes are higher (less efficient) than the average for 2011 Program homes (U-0.065). All conditioned/ambient average R-values and U-values for 2011 baseline and 2011 Program homes are less energy efficient than current UDRH inputs.

Ceilings

The unweighted (R-34.5) and weighted (R-34.6) average R-values for flat ceiling insulation in 2011 baseline homes are slightly lower than the average R-value in 2011 Program homes (R-35.0). The average U-value of flat ceilings in baseline homes (U-0.051 both unweighted and weighted) is much higher (less energy efficient) than in 2011 Program homes (U-0.058); the difference in U-values between 2011 baseline and 2011 Program homes is statistically significant. Average R-values and U-values for both 2011 baseline and 2011 Program homes are more energy efficient than current UDRH inputs.

The average R-value of cathedral ceiling insulation is similar in 2011 baseline homes (R-33.0 unweighted and R-32.8 weighted) and 2011 Program homes (R-33.2). The unweighted (U-0.043) and weighted (U-0.044) average U-values for cathedral ceilings in 2011 baseline homes are higher (less energy efficient) than in 2011 Program homes (U-0.036). Average R-values and U-values for both 2011 baseline and 2011 Program homes are more energy efficient than current UDRH inputs.

Conditioned/Basement Floors

The unweighted (R-18.3) and weighted (R-17.6) average R-values for conditioned/basement floor insulation in 2011 baseline homes are lower than the average R-value in 2011 Program homes (R-25.9); the difference in R-values between 2011 baseline and 2011 Program homes is statistically significant. The unweighted (U-0.111) and weighted (U-0.119) average U-values for conditioned/basement floors in 2011 baseline homes are higher than the average U-value in 2011 Program homes (U-0.047); the difference in U-values between 2011 baseline and 2011 Program homes is statistically significant. Average R-values and U-values for both 2011 baseline and 2011 Program homes are less energy efficient than current UDRH inputs.

Foundation Walls

Average foundation wall insulation levels in 2011 baseline homes with conditioned basements (R-16.8 unweighted and R-18.6 weighted) are higher than the average R-value of 14.2 in 2011 Program homes. Average R-values for both 2011 baseline and 2011 Program homes are higher than current UDRH input of R-13.0.

The unweighted average R-value of foundation wall insulation in homes with unconditioned basements (R-0.8) is the same as the average R-value for 2011 Program homes (R-0.8); the weighted average R-value for 2011 baseline homes (R-1.1) is higher than the average R-0.8 for 2011 Program homes. Average R-values for both 2011 baseline and 2011 Program homes are lower than the current UDRH input of R-3.1. Building code does not require these foundation walls to be insulated.

Duct Insulation

The average R-value of duct insulation on attic supply ducts is lower in 2011 baseline homes (R-7.3 unweighted and R-7.6 weighted) than in 2011 Program homes (R-7.8); the difference between 2011 baseline and Program homes is statistically significant. Average attic supply duct insulation levels in both 2011 baseline and 2011 Program homes fall short of the 2009 IECC R-8 requirement for attic supply ducts.

Average duct insulation levels in 2011 baseline homes for ducts in other unconditioned spaces (R-6.5 unweighted and R-6.6 weighted) are higher than in 2011 Program homes (R-6.3). Average R-values in both 2011 baseline and 2011 Program homes are higher than the current UDRH input of R-4.68 and exceed the 2009 IECC requirement of R-6 insulation for non-attic-supply ducts in unconditioned space.

Duct Leakage

Average duct leakage in 2011 baseline homes (18.9 CFM25/100 ft^2 unweighted and 20.0 weighted) is much higher than in 2011 Program homes (4.3 CFM25/100 ft^2) and the difference is statistically significant. Weighted and unweighted average duct leakage in 2011 baseline homes are higher than the current UDRH input of 14 CFM25/100 ft^2 and higher than the 2009 IECC requirement of 8 or lower CFM25/100 ft^2 leakage to the outside.

Air Infiltration—ACH50

Average air infiltration is also lower in 2011 Program homes and the difference between 2011 baseline and 2011 Program homes is statistically significant. Average air leakage rates in both 2011 baseline homes (unweighted average 5.81 ACH50 and weighted average 5.96 ACH50) and 2011 Program homes (3.93 ACH50) are lower than the current UDRH input of 6.72 ACH50.

HERS Indices

Average HERS indices show a clear difference in the overall energy efficiency of 2011 baseline and 2011 Program homes. The average HERS index for 2011 Program homes of 66 is much lower (more energy efficient) than the unweighted average 85 HERS index and weighted average 87 HERS index for 2011 baseline homes. The difference between 2011 baseline and 2011 Program homes is statistically significant.

5 Code Compliance

An exploratory analysis of 2009 IECC was conducted based on the 40 inspected homes using four different compliance paths. The four compliance paths are the Prescriptive, Home Energy Rating, Annual Energy Cost, and Overall Building UA compliance paths. In addition, compliance was assessed using the 2009 IECC checklist developed by Pacific Northwest National Laboratory (PNNL). The Home Energy Rating, Annual Energy Cost, and Overall Building UA compliance paths were all assessed using reports and calculations available through the REM/Rate software. This approach allowed the evaluation team to leverage the REM/Rate files that were compiled for other pieces of this report and utilize those files for this analysis. It should be noted that the purpose of this study is not to assess code compliance for each inspected home, nor is it to evaluate code enforcement. Details on the compliance path utilized by each of the audited homes would be necessary to conduct such an evaluation, and this information was not available for all homes; the compliance approach was determined for only 30 of the 40 inspected homes. In addition, the sample for this project was designed to mimic the Program housing mix, not the state's housing mix. Therefore, the results presented here are not indicative of actual code compliance but serve as a tool for assessing specific prescriptive measure compliance and how homes would likely perform under different performance based compliance paths.

5.1 Compliance Paths

5.1.1 Checklist Compliance

The 2009 IECC checklist, developed by PNNL, includes 63 compliance items, and each item is assigned either one, two, or three points, based on the item's relative importance.[9] There are a total of 130 points available. Building level checklist compliance is calculated as the total points for items marked compliant divided by total points for items marked either compliant or not compliant—this way homes are not penalized if an item is not applicable or not observable.

The checklist was developed as a means of measuring statewide compliance. For determining statewide compliance, there are two possibilities:

- Determine the percentage of compliant homes (those having a checklist score equal to 100%)
- Take a simple average of the house-level compliance scores

PNNL states a preference for the second method, as it provides a finer level of detail in the progress of a state in reaching 90% compliance.

The checklist allows compliance to be assessed depending on which compliance approach the builder used: the prescriptive approach, the UA trade-off approach, or the performance approach.

[9] The checklist was not modified for the purposes of this study. The original checklist can found here http://www.energycodes.gov/arra/compliance_checklists.stm.

The checklist is populated differently depending on the compliance approach the builder selected. Under the prescriptive approach, applicable and observable items are simply marked as compliant or non-compliant. Under the trade-off or performance approaches, certain measures may be marked as compliant even if they do not meet the prescriptive compliance levels identified in the checklist, but they are consistent with how the builder designed the building to comply. As the 2009 IECC checklist instructions note, this is done assuming “a valid worksheet or software report was submitted showing a compliant building.”[10] The checklist is not a compliance path, but instead a means of assessing compliance. For example, if a home achieved compliance via the trade-off approach then the builder should have submitted a REScheck report to the building department that indicated compliance with the energy code. In this case, the home may not meet the prescriptive requirements listed in the checklist, but it would be considered compliant for all shell measures because the REScheck documentation proves that the home complied via the trade-off approach.

To determine which compliance approach (i.e., prescriptive, UA trade-off, or performance) each audited home used, the evaluation team contacted individual building departments and asked them about the specific sites visited for this study. Ultimately, the compliance approach was verified for 30 of the 40 inspected homes. The compliance approach was assumed to be prescriptive for the 10 sites where the compliance approach was unknown. Of the 30 homes where the compliance approach was verified, eight used REScheck (i.e., UA trade-off) and 22 used the prescriptive approach.

5.1.2 Prescriptive Compliance

The Prescriptive path refers to a compliance path under which various aspects of a home are inspected individually to determine compliance with prescriptive requirements. Under the prescriptive path, items are typically assessed in one of two ways:

1) The item does not meet, meets, or exceeds a minimum efficiency value provided for it (e.g., wall insulation R-value)
2) The item either is, or is not, compliant on a yes/no basis (e.g., floor insulation installation quality)

In this report, compliance under the prescriptive path is assessed by looking only at the 2009 IECC prescriptive insulation requirements.[11] Compliance is assessed looking at the percent of homes that meet each prescriptive insulation requirement and the percent of applicable prescriptive insulation requirements met in each home. Three prescriptive requirements—slab insulation, window U-values, and skylight U-values—were not addressed in this analysis. This is because auditors were able to verify the insulation and/or fenestration values for these measures at only a few sites and, rather than make assumptions, these measures are excluded from the

[10] It was assumed that all inspected homes submitted the necessary paperwork to achieve compliance with the energy code as all of the inspected homes were occupied and therefore should have an occupancy permit.

[11] This analysis focused on prescriptive insulation requirements. Lighting is addressed in the checklist portion of this section (Table 5-3).

prescriptive compliance analysis. Heating, cooling, and water heating measures were excluded from this analysis as the 2009 IECC only requires that mechanical equipment meet the minimum federal efficiency standards; all of the mechanical equipment inspected as a part of this study either meets or exceeds the minimum federal efficiency standards for mechanical equipment. The standards for mechanical equipment are mandatory requirements that are required under any compliance approach. These items, along with many other mandatory requirements, were not considered when assessing prescriptive compliance.

5.1.3 Home Energy Rating Compliance Path (Performance)

HERS ratings are performed using REM/Rate software, where REM/Rate compares the “design” or “as-built” home to the “reference” home. The current reference home in REM/Rate is based on the 2004 IECC.[12] To calculate a HERS index, REM/Rate models the reference home to be configured similar to the as-built home (e.g., size, shape, orientation), but with the reference home efficiency measures based on the 2004 IECC prescriptive requirements. A home built to 2004 IECC prescriptive code requirements should score a HERS index of roughly 100; a home that is more energy efficient will have a HERS index less than 100. Several states allow for compliance under the Home Energy Rating Path, with varying HERS scores being considered compliant. For example, in Massachusetts, while the 2006 IECC was still in effect, homes were considered compliant with the energy code if they achieved a HERS rating of 100 or less. For homes required to meet the 2009 IECC, Massachusetts requires a HERS index of 75 or lower for 1-4 unit residential buildings and 70 or lower for residential buildings with five or more units.[13] Rhode Island does not currently offer a Home Energy Rating compliance path.

5.1.4 Annual Energy Cost Compliance Path (Performance)

The Annual Energy Cost compliance path is based on REM/Rate models and compares the as-built home to the 2009 IECC reference home, which is built to the 2009 IECC prescriptive requirements. The Annual Energy Cost compliance path only compares the as-built and reference home for heating, cooling, and domestic water heating costs. In other words this compliance path compares the simulated costs of heating, cooling, and water heating for the as-built and reference homes. If the as-built home has annual energy costs that are less than the reference home then the home is considered compliant. This compliance path does not consider other factors that are typically modeled in REM/Rate. Examples of measures not addressed are lighting, appliances, and photovoltaics.

5.1.5 Overall Building UA Compliance Path (Trade-off)

The Overall Building UA trade-off path is an approach that compares the overall UA-value of the as-built home to the overall UA-value of an identically configured home built to meet the 2009 IECC prescriptive requirements. The overall UA-value of a home is calculated by summing

[12] Brian Christensen, email message to author, January 24, 2012.
[13] http://www.mass.gov/eopss/docs/dps/inf/780-8th-51.pdf

the UA-values for the primary shell measures of the home (e.g., ceilings, above-grade walls, frame floors, etc.). This analysis was conducted using REM/Rate. Although the basic calculations are similar to the REScheck software developed by the Department of Energy and the Building Energy Codes Program (BECP)[14] there are several key differences between the REM/Rate Overall Building UA approach and REScheck. These differences include, but are not limited to, different approaches used to calculate insulation U-values and different framing assumptions. Ultimately, these differences make it much more difficult to achieve compliance using REM/Rate as opposed to using REScheck.

5.2 Compliance Results

Table 5-1 displays summary statistics of the checklist compliance results. The data are based on results from analysis of up to 63 checklist items. Weighted results indicate compliance with 58% of the possible points on the 2009 IECC checklist.

Table 5-1: Checklist Compliance Results*

Statistic	Checklist		
	Points Possible	Points Received	Compliance
Minimum	28	5	18%
Maximum	65	49	92%
Unweighted Average	**42**	**24**	**56%**
Weighted Average	**42**	**25**	**58%**
Median	41	24	58%
Percent of Homes Compliant	**0%****		
Weighted % of Homes Compliant	**0%****		

*Statistics are for each category (points possible, points received, and compliance). For example, the maximum compliance of 92% represents the highest compliance score achieved by a home in the sample—not the score of the home that achieved the maximum possible points.

**Percent of homes with 100% checklist compliance.

[14] http://www.energycodes.gov/rescheck/download.stm

Table 5-2 displays the minimum, maximum, average, and median compliance results under the Prescriptive, Home Energy Rating, Energy Cost Compliance, and Overall Building UA compliance paths for the 40 inspected homes. The left half of the table displays results under the prescriptive compliance path. Weighed results are 38% compliance with the prescriptive insulation requirements considered. The Annual Energy Cost and the Overall Building UA trade-off compliance path results are presented as a percentage above or below code. A positive percentage represents homes meeting or exceeding code, while a negative percentage represents homes below code. This does not represent the percent of homes that pass or fail, but the degree to which the average of our sample falls short of or exceeds the code. Weighted results indicate compliance is 26% below code using the Annual Energy Cost compliance path, and 48% below code using the Overall Building UA trade-off approach. In other words, on average, annual energy costs are 26% higher than the 2009 IECC reference home and overall UA values are 48% higher than the 2009 IECC reference home.[15] Weighted results are 4% compliance under the Annual Energy Cost compliance path and 6% under the Overall Building UA trade-off path. Finally, if Rhode Island offered a Home Energy Rating compliance path, and the 40 inspected homes selected this compliance approach, the compliance rate would be 25%; the weighted compliance rate is 15%.

Table 5-2: Prescriptive Compliance and Compliance Based on REM/Rate

Statistic	Prescriptive			Compliance Paths using REM/Rate Results		
	Applicable and Observable Criteria	Criteria Met/ Exceeded	Percent of Criteria Met	HERS Index*	Energy Cost Compliance	UA Compliance
Minimum	2	0	0%	62	-55%	-173%
Maximum	6	5	100%	117	7%	10%
Unweighted Average	4	2	39%	**85**	**-19%**	**-42%**
Weighted Average	4	2	38%	**87**	**-26%**	**-48%**
Median	5	2	33%	84.5	21%	-28%
Percent of Homes Compliant				**25%**	**5%**	**10%**
Weighted % of Homes Compliant				**15%**	**4%**	**6%**

*The lower the HERS index the more energy efficient.

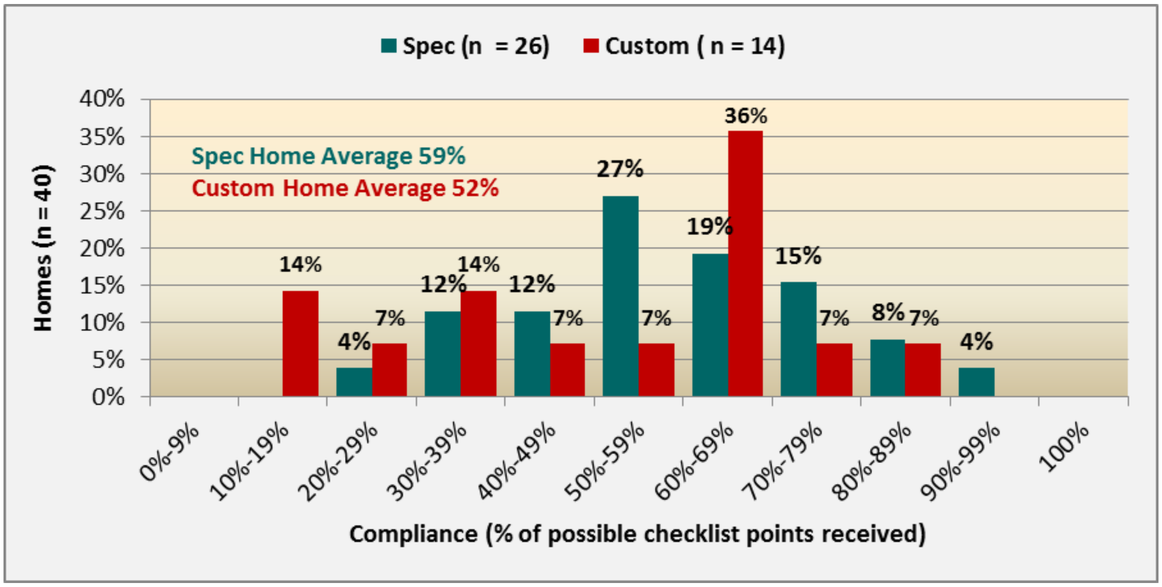
[15] Lower overall UA values result in higher compliance under the UA trade-off approach.

5.2.1 Checklist Compliance Detailed Results

As previously mentioned, the actual compliance path of choice was determined for 30 of the 40 inspected homes. Eight complied under the trade-off approach and 22 under the prescriptive approach. The remaining 10 sites were assumed to have complied under the prescriptive path.

Figure 5-1 shows the distribution of PNNL checklist compliance scores. Only one home received more than 90% of the points possible, and no homes received all of the points possible. On average, homes received 56% of possible checklist points.

Figure 5-1: Distribution of House Level Compliance



Sixty-three requirements were considered for the checklist compliance analysis. Table 5-3 summarizes compliance percentages for 14 item groups. Items that were not applicable or observable were deemed unverifiable. The “Percent Verifiable” column in Table 5-3 reflects how often the items were verifiable—the lower the percent verifiable, the less precise the compliance estimate is for an item group. While few item groups surpass 90% compliance, most are over 60%. Lighting has the lowest compliance percentage (excluding plumbing penetrations, which could only be verified at two homes), because at nearly every home less than 50% of permanently installed bulbs were high efficacy. Walls, the item group that makes up the largest portion of the overall compliance score, are 69% compliant, but only 18% of the requirements were verifiable.

Table 5-3: Checklist Compliance by Item Group

Compliance Item Group	Number of Checklist Items*	Percent Verifiable	Compliance			
			All Homes	Spec (n = 26)	Custom (n = 14)	All Homes Weighted
Lighting	1	95%	8%	8%	7%	8%
Windows	8	5%	100%	100%	100%	100%
Ceilings	4	49%	76%	82%	64%	81%
Floors	2	81%	57%	63%	48%	61%
Walls	12	18%	69%	68%	72%	68%
Slab	3	5%	83%	100%	80%	98%
Crawl Space	3	n/a	n/a	n/a	n/a	n/a
Air Sealing	8	100%**	78%	83%	69%	81%
Ducts	5	37%	45%	43%	50%	44%
Fireplace	1	18%	57%	67%	50%	65%
Plumbing Penetrations	1	5%	0%	n/a	0%	0%
Doors	2	50%	63%	65%	56%	64%
Fans and Vents	1	100%	100%	100%	100%	100%
Other	12	24%	25%	23%	28%	23%

*Details on the items included in the compliance group can be found in Appendix B Code Compliance Details
**Air sealing was evaluated based on the blower door results for all 40 inspected homes. Auditors were only able to verify the air sealing checklist items requiring visual inspection 15% of the time.

5.2.2 Prescriptive Compliance Detailed Results

Nine requirements were considered for the prescriptive compliance analysis. Table 5-4 shows the percentage of homes that comply with applicable 2009 IECC prescriptive requirements. Weighted results are 17% compliance with the R-20 wood framed wall insulation requirement. Low wood-framed wall insulation compliance drove down overall prescriptive insulation compliance. A higher percentage of homes met or exceeded ceiling insulation requirements—weighted results are 53% compliance with the flat ceiling requirement of R-38 and 65% with the cathedral requirement of R-38 (or R-30 if under 500 sq. ft.). Weighted results are 38% compliance with the 2009 IECC requirement for floors over unconditioned basements (R-30). Overall, 5% percent of inspected homes complied with all applicable insulation requirements; weighted compliance is 4% overall.

Table 5-4: Compliance with IECC Prescriptive Insulation Requirements

Measure or Characteristic	IECC 2009 Prescriptive Requirements	Number of Homes	All Homes Raw Data	Spec	Custom	All Homes Weighted Data
Wood Framed Wall Insulation	R-20	40	9 (23%)	4 (15%)	5 (36%)	17%
Foundation Wall	R-10/R-13 (cont./cavity)	7	5 (71%)	3 (60%)	2 (100%)	64%
Duct Insulation	R-8 attic supply R-6 all other ducts	23*	8 (35%)	6 (37%)	2 (29%)	37%
Flat Ceiling Insulation	R-38	35	18 (51%)	13 (54%)	5 (45%)	53%
Cathedral Ceiling Insulation	R-38 (R-30 for buildings less than 500 sq. ft.)	19	11 (58%)	6 (67%)	5 (50%)	65%
All Ceiling Insulation Requirements		40	20 (50%)	13 (50%)	7 (50%)	50%
Floors Over Unconditioned Space Insulation R-Value (basement)	R-30 or cavity filled	27	9 (33%)	6 (30%)	3 (43%)	31%
Floors Over Unconditioned Space Insulation R-Value (garage)	R-30 or cavity filled	13	7 (54%)	5 (63%)	2 (40%)	60%
Floors Over Unconditioned Space (outside)	R-30 or cavity filled	10	8 (80%)	4 (67%)	4 (100%)	70%
Floors over unconditioned space (crawlspace)	R-30 or cavity filled	6	0 (0%)	0 (0%)	0 (0%)	0%
All Floors Over Unconditioned Space Prescriptive Requirement	R-30	40	15 (38%)	10 (38%)	5 (36%)	38%
Met All Applicable IECC 2009 Requirements		40	2 (5%)	1 (4%)	1 (7%)	4%

*Excludes one home where the duct insulation was unknown.

As previously mentioned, the compliance path was confirmed for 30 out of 40 homes in the sample. The evaluation team confirmed that builders chose the prescriptive compliance path at 22 out of the 30 homes, while the trade-off approach was chosen for the other eight homes. The compliance path was assumed to be prescriptive for the remaining 10 homes. Table 5-5 shows prescriptive compliance for the 22 homes where builders selected the compliance path and the 10 homes where the prescriptive approach was assumed.

Table 5-5: Prescriptive Compliance for Homes Utilizing the Prescriptive Path[16]

Measure or Characteristic	IECC 2009 Prescriptive Requirements	Number of Homes	All Homes Raw Data	Spec	Custom	All Homes Weighted Data
Wood Framed Wall Insulation	R-20	32	8 (25%)	3 (16%)	5 (38%)	18%
Foundation Wall	R-10/R-13 (cont./cavity)	6	3 (50%)	1 (25%)	2 (100%)	33%
Duct Insulation	R-8 attic supply R-6 all other ducts	17*	4 (24%)	3 (27%)	1 (17%)	26%
Flat Ceiling Insulation	R-38	28	16 (57%)	12 (67%)	4 (40%)	64%
Cathedral Ceiling Insulation	R-38 (R-30 for buildings less than 500 sq. ft.)	17	11 (65%)	6 (86%)	5 (50%)	82%
All Ceiling Insulation Requirements		32	18 (56%)	12 (63%)	6 (46%)	61%
Floors Over Unconditioned Space Insulation R-Value (basement)	R-30 or cavity filled	20	6 (30%)	4 (29%)	2 (33%)	29%
Floors Over Unconditioned Space Insulation R-Value (garage)	R-30 or cavity filled	13	7 (54%)	5 (63%)	2 (40%)	60%
Floors Over Unconditioned Space (outside)	R-30 or cavity filled	10	6 (60%)	4 (67%)	2 (50%)	65%
Floors Over Unconditioned Space (crawlspace)	R-30 or cavity filled	5	0 (0%)	0 (0%)	0 (0%)	0%
All Floors Over Unconditioned Space Prescriptive Requirement	R-30	32	11 (34%)	8 (42%)	3 (23%)	40%
Met All Applicable IECC 2009 Requirements		32	1 (3%)	1 (5%)	0 (0%)	5%

*Excludes one home where the duct insulation was unknown.

[16] This includes 10 homes where the compliance approach was not verified and was assumed to be prescriptive.

5.2.3 Annual Energy Cost Compliance Path (Performance) Detailed Results

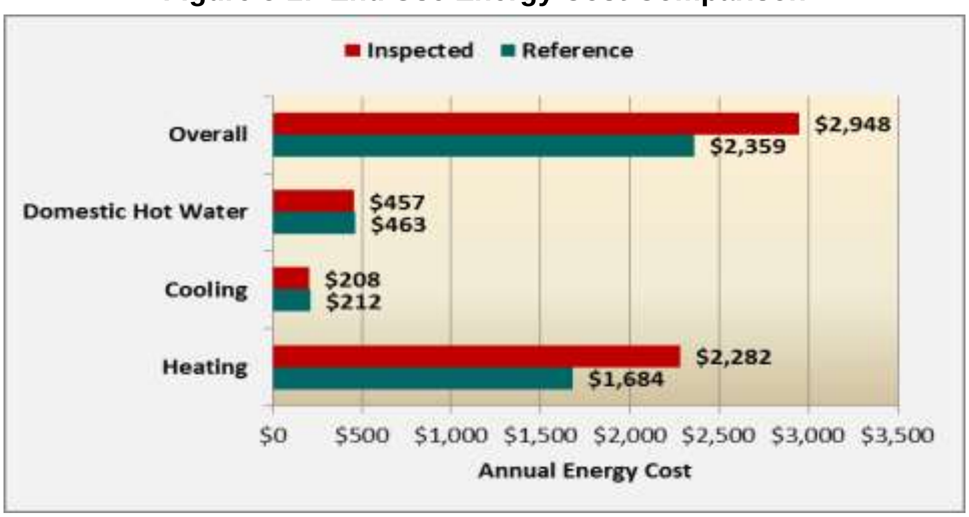
As shown in Table 5-6, weighted results are 4% compliance under the Annual Energy Cost Compliance approach with overall annual energy costs lower than the 2009 IECC reference home. Note, the annual energy cost compliance path does not consider the effects of high efficiency mechanical equipment. In fact, the heating, cooling, and water heating equipment are the same in the "as-built" and "reference" models under this compliance path. Table 5-6 displays the energy cost compliance broken up by end use, but it is important to note that these categories are meant to encapsulate the effect of key shell measures on compliance, not the effect of high efficiency mechanical equipment.

Table 5-6: Energy Cost Compliance Path Results, % Complying Homes

End Use	n	All Homes (n = 40)	Spec (n = 26)	Custom (n = 14)	Weighted
Heating	40	2 (5%)	1 (4%)	1 (7%)	4%
Cooling	40	19 (48%)	13 (50%)	6 (43%)	49%
Domestic Hot Water	40	33 (83%)	22 (85%)	11 (79%)	84%
Overall	40	2 (5%)	1 (4%)	1 (7%)	4%

Overall compliance is driven down by the low compliance for the heating end use. For the cooling and water heating end uses, the weighed results are 49% and 84% compliance respectively, where annual energy costs are lower than the 2009 IECC reference home. On average, however, these two end uses combine to account for only 26% of the total annual energy costs considered for the energy cost compliance approach. Heating accounts for the remaining 74% of total annual energy costs considered, and only 5% of homes have annual heating costs lower than the 2009 IECC reference home. The average inspected home has estimated annual energy costs that are 18% higher than the 2009 IECC reference home. Figure 5-2 shows weighted average annual energy costs by end-use for the 2009 IECC reference home and inspected (design) homes.

Figure 5-2: End Use Energy Cost Comparison



5.2.4 Overall Building UA Compliance Path (Trade-Off) Detailed Results

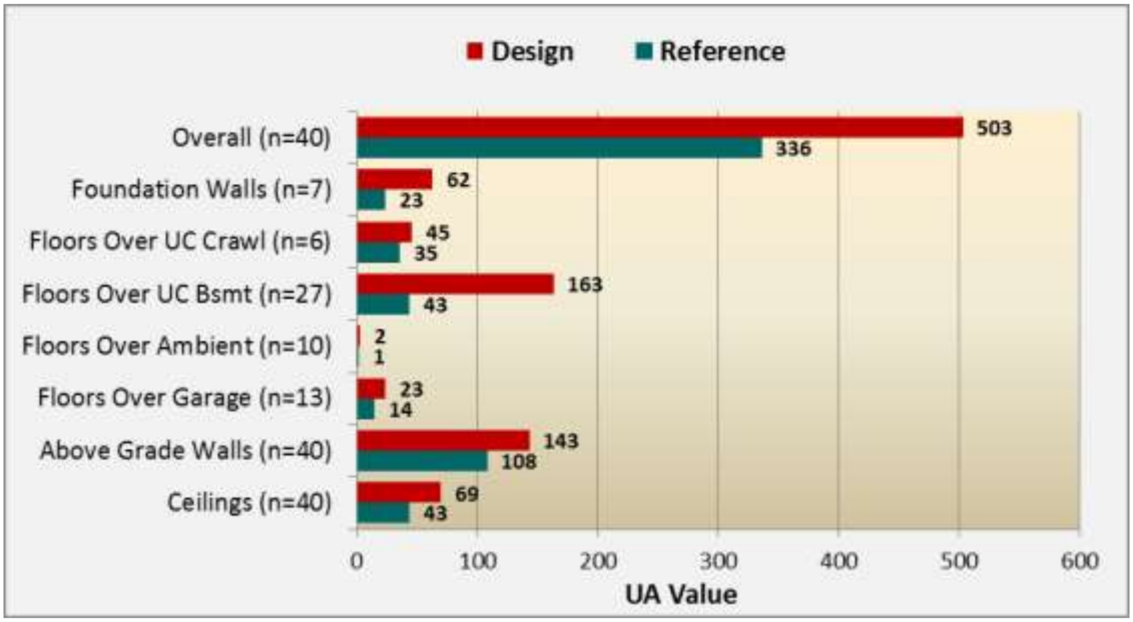
Table 5-7 shows the percent of homes where the calculated UA value complies with the IECC 2009 requirement by component. Note, these results are not necessarily indicative of what compliance might be via the UA trade-off approach assessed using REScheck software as opposed to REM/Rate. Four measures—skylights, windows, doors, and slab floors—are excluded from the table as values for these measures were rarely verified onsite and default values were typically used in the REM/Rate models; while these values are excluded from the table they are still part of the overall UA value and, therefore, feed into the overall UA-tradeoff compliance. Weighted results are 6% compliance with 2009 IECC via the UA trade-off path. Weighted UA compliance is very low for key shell measures such as above grade walls (6%), frame floors over unconditioned basements (0%), and frame floors over garages (0%). This is not to say that these components never meet prescriptive requirements. UA compliance, when calculated in REM/Rate, accounts for compression and gaps in insulation, effectively lowering any given assembly R-value (or raising the U-value). These adjustments can lead to component specific non-compliance under the UA trade-off path, even though a measure might meet the prescriptive requirement, and might comply under the REScheck based UA trade-off approach. For example, weighted results for frame floors over unconditioned basements are 31% compliance with the prescriptive requirement (Table 5-4), but 0% under the UA trade-off approach. All of the floors that complied with the prescriptive requirement had R-30 insulation (the prescriptive requirement), but they were often assigned a grade II or grade III installation and, therefore, the UA value for the assembly falls below that of the 2009 IECC reference home. Foundation walls (30%) show some of the highest compliance rates among the measures for which auditors were able to record reliable data.

Table 5-7: UA Compliance by Component

Component	All Homes (n = 40)	Spec (n = 26)	Custom (n = 14)	Weighted
Ceiling	4 (10%)	2 (8%)	2 (14%)	8%
Above Grade Wall	4 (10%)	1 (4%)	3 (21%)	6%
Floors Over Garage	0 (0%)	0 (0%)	0 (0%)	0%
Floors Over Ambient	2 (20%)	0 (0%)	2 (50%)	5%
Floors Over Unconditioned Basement	0 (0%)	0 (0%)	0 (0%)	0%
Floors Over Unconditioned Crawlspace	0 (0%)	0 (0%)	0 (0%)	0%
Foundation Walls	4 (31%)	3 (30%)	1 (33%)	30%
Overall	4 (10%)	1 (4%)	3 (21%)	6%

Figure 5-3 compares average UA values from the sample to the 2009 IECC reference home UAs by component and overall.[17] It should be noted that under the UA compliance path, and in Figure 5-3, a home is considered to be in compliance if its UA value is less than that of the reference home.

Figure 5-3: UA Comparison



5.2.5 Variability in Compliance Based on Approach

This section refers to unweighted data in order to reflect the actual compliance percentages under the various compliance paths.

Compliance of the inspected homes was least when determined using the Annual Energy Cost approach. On average, the inspected homes are estimated to be 19% below code using this approach and only 5% of the inspected homes would be compliant with 2009 IECC.

When assessed using the other performance compliance methods (i.e., the Overall UA and the Home Energy Rating compliance paths), compliance rates were determined to be only slightly better than those determined using the Annual Energy Cost method. Using the Overall UA compliance path, 10% of the homes would have complied with the code, and the average Overall UA value was found to be 42% more than allowed by the code. The Home Energy Rating path gave higher compliance rates—23% of the homes would comply using this method. There are a number of reasons for the higher compliance rate using the Home Energy Rating path. This path allows homes to be assessed as a system. This allows for whole building tradeoffs with respect to

[17] As is the case with Table 5-7, this figure excludes skylights, windows, doors, and slab floors although these values still feed into the overall UA value.

efficiency and energy usage. Also, key inputs such as low air and duct leakage are considered in a performance approach and including such factors typically results in higher compliance rates.

Again, it is important to remember that it is not the purpose of this study to report how many of the inspected homes complied with code. The compliance approach was determined for only 30 out of the 40 inspected homes. That said, without knowing what compliance path the remaining 10 homes were permitted under it is impossible to accurately assess an overall compliance rate. It is also worth noting that the 40 homes were sampled to reflect the mix of homes in the Rhode Island Program, not the mix of homes in the state of Rhode Island. Therefore, even if the compliance path was known for all 40 homes (or compliance was assessed using the subset of 30 homes for which the compliance path is known), the compliance rate would not be indicative of the state due to sampling. Finally, the REM/Rate software compliance assessments are not necessarily consistent with the tools code officials and builders use to assess compliance. For example, we know there are significant differences between the REM/Rate Overall UA approach and the commonly accepted and used REScheck software and know that compliance under the REM/Rate UA approach will often be lower than when using REScheck. As stated earlier, the purpose of this report is not to assess either individual home or state level code compliance or code enforcement; however, study findings suggest there is room for improvement.

6 Homeowner On-Site Survey

The homeowners of the 40 sites were asked to complete a brief survey during the onsite audits. The survey addressed:

- How home was purchased
- Comfort of home
- Complaints about home
- If energy efficiency was discussed between the homeowner and the real estate agent or builder
- Importance of buying an energy-efficient home
- Who specified various building components, HVAC equipment, and appliances (homeowner or builder)
- Homeowner perception of the energy efficiency of home and various components
- Awareness of the ENERGY STAR label on homes
- Homeowner demographics including:
    - First time home buyer or previously owned home
    - How long expect to stay in home
    - Education
    - Age
    - Income

Combining information collected during the inspections with information provided by homeowners provides insight into how aware homeowners are of the building materials and mechanical equipment in their homes, and whether or not homeowners who think they have energy-efficient homes really do. The results presented in this section are unweighted.

6.1 How Homes Were Purchased

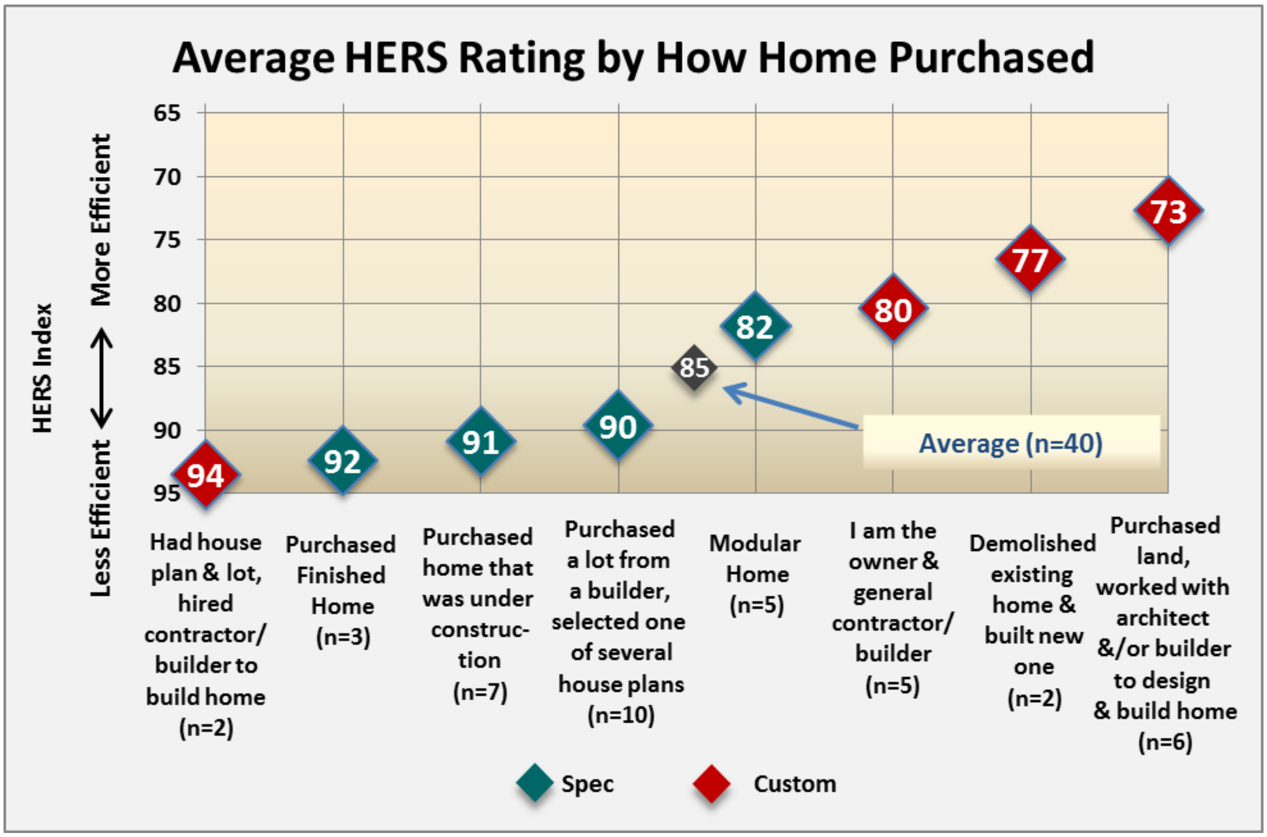
Table 6-1 displays the various ways the homes were purchased and divides them into two major categories: custom homes and spec homes. Custom homes include all cases in which the homeowner had a building lot and initiated the home-building process. Spec homes include all homes where the builder owned the land and either offered potential buyers a choice of several home plans or started construction without a buyer involved. Almost two-thirds (65%) of the homes are spec homes, and just over one-third (35%) are custom homes. The most commonly cited method of purchasing a new home is to purchase a lot from a builder and select one of several house plans offered by the builder (25%), followed by purchasing a home that was under construction (18%). The owner was the builder or general contractor for five (13%) of the 40 homes.

Table 6-1: How Home Was Purchased

How Home Was Purchased	Number of Homes	Percent of Homes
Spec Homes		
Purchased a lot from a builder, selected one of several house plans offered by builder	10	25%
Purchased a home that was under construction	7	18%
Modular Home	5	13%
Purchased a finished home	3	8%
Built home and rented out	1	3%
Subtotal Spec Homes:	26	65%
Custom Homes		
Purchased land and worked with an architect and/or builder to design and build the home	5	13%
I am the owner and general contractor/builder	5	13%
Had a house plan and a lot and hired a contractor/builder to build the home	2	5%
Owner demolished existing home and built a new one	2	5%
Subtotal Custom Homes:	14	35%

Figure 6-1 displays the average HERS rating for homeowners by the various ways the homes were purchased. The average HERS rating across all 40 homes is 85. [18] On average, homeowners who purchased land and worked with an architect and/or builder to design and build the home have the most energy-efficient homes (average HERS rating of 73), while homeowners who had a house plan and a lot and hired a contractor/builder to build the home have the least energy-efficient homes (average HERS rating of 94). The average HERS rating for the most commonly cited method of purchasing a new home (to purchase a lot from a builder and select one of several house plans offered by the builder) is 90, which is less energy efficient than the average HERS rating of 85 across all 40 homes.

Figure 6-1: Average HERS Rating by How Home Purchased



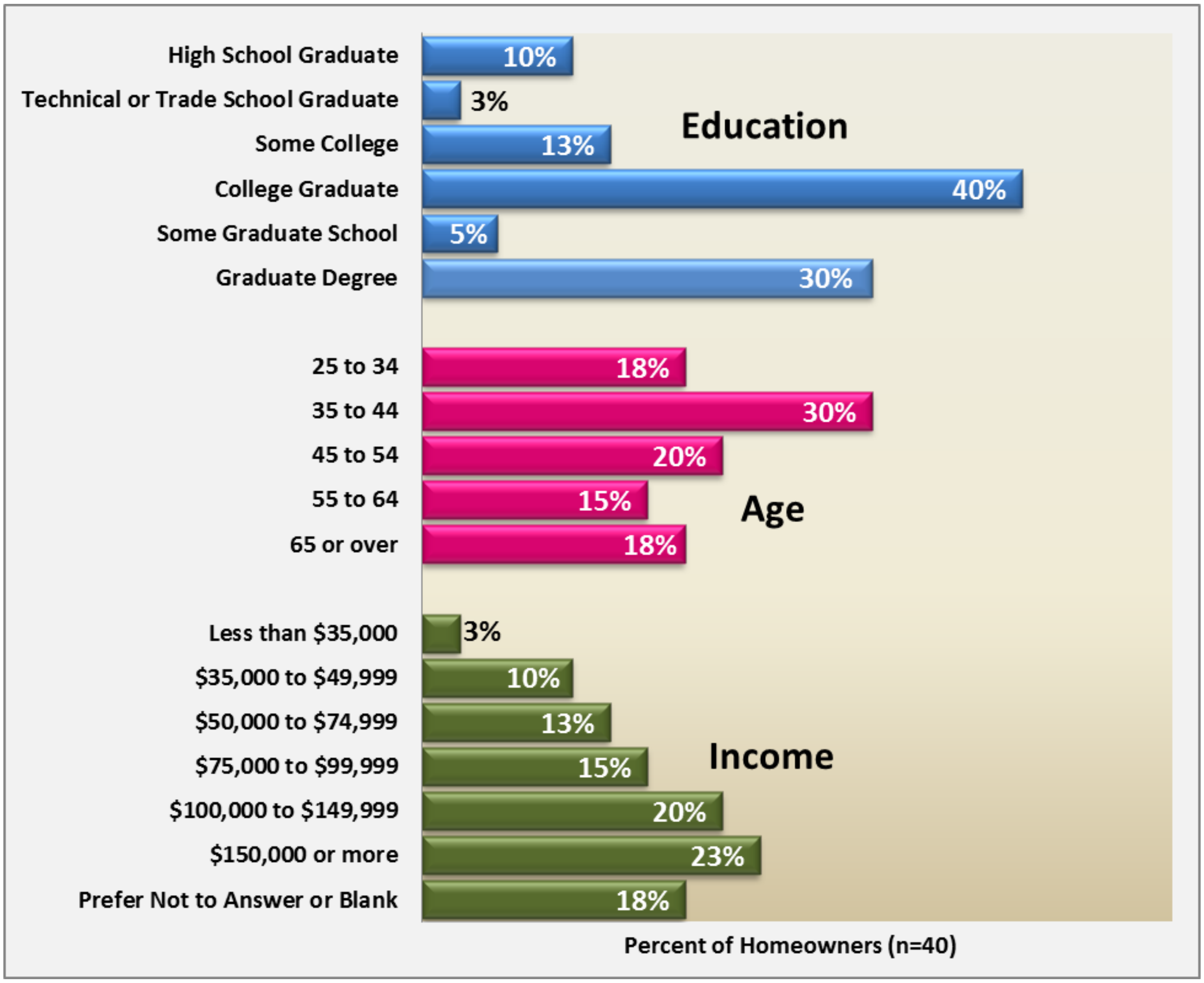
*For this figure, the spec home that was built and rented out is grouped with "purchased land and worked with an architect and/or builder to design and build the home." While it was built for the spec market and is treated as a spec home in the rest of this report, this home is very energy efficient (HERS 66) and the owner checked "purchased land and worked with an architect and/or builder to design and build the home" on the survey.

[18] A home built to the specifications of the HERS Reference Home (based on the 2004 International Energy Conservation Code) scores a HERS Index of 100, while a net zero energy home scores a HERS Index of 0. Each one-point decrease in the HERS Index corresponds to a 1% reduction in energy consumption compared to the HERS Reference Home.

6.2 Homeowner Demographics

The homeowners are a diverse group with representation across an array of education, age, and income levels. Figure 6-2 shows the percentage of homeowners falling into each education, age, and income level category. On the whole, the homeowners tend to be well-educated with annual incomes above the state average.[19] The majority of homeowners (75%) are college graduates. Almost one-fifth (18%) of the homeowners did not provide income information. However, over one-half (52%) of the homeowners who did provide income information have an annual income of $100,000 or more.

Figure 6-2: Homeowner Education, Age, and Income



[19] The median household income in Rhode Island for the years 2006 through 2010 was $53,243 http://quickfacts.census.gov/qfd/states/44000.html.

has at least a bachelor's degree and an annual income of at least $100,000.

Figure 6-3 displays the number of homeowners within each educational attainment level that fall into each income category. Over one out of three homeowners (35%) has at least a bachelor's degree and an annual income of at least $100,000.

Figure 6-3: Homeowner Education by Income

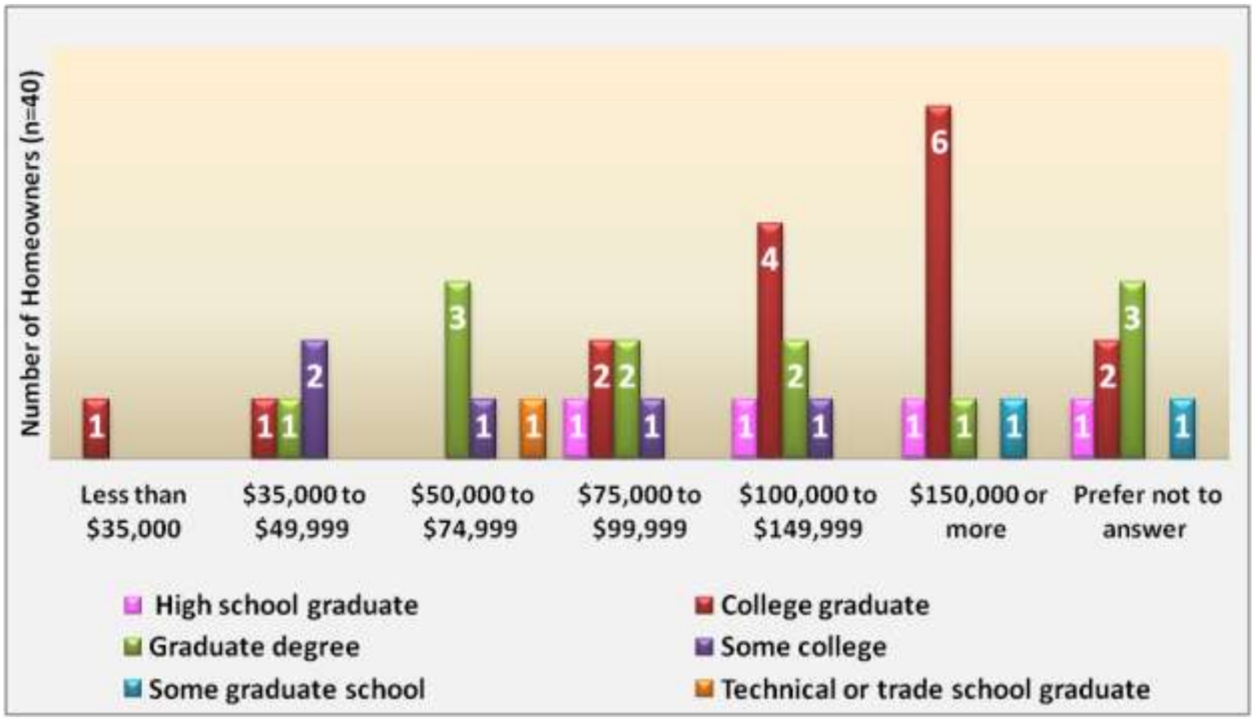


Figure 6-4 displays the number of homeowners within each age category that fall into each income category. Over one out of three homeowners (35%) is aged 25 to 54 with an annual income of $100,000 or more. Four out of the five homeowners with annual incomes less than $50,000 are aged 65 or over. All five of the youngest homeowners (aged 25 to 34) who provided income information have annual incomes of $100,000 or more.

Figure 6-4: Homeowner Age by Income

Figure 6-5 displays the average HERS rating for homeowners of each educational attainment level. Variation in the average HERS rating by educational attainment level is generally small, and there is no clear relationship between average HERS rating and education. Homeowners whose highest educational attainment level is high school (average HERS 82) or a graduate degree (average HERS 83) have the most efficient homes, while those with some graduate school own the least efficient homes (average HERS 93). The average HERS rating for the most populous educational attainment group (college graduates) is 86, which is one index point higher (less energy efficient) than the average HERS rating of 85 across all 40 homes. The educational attainment levels of the five owner/builders are as follows: one with some college, three college graduates, and one with a graduate degree.

Figure 6-5: Homeowner Education by Average HERS Rating

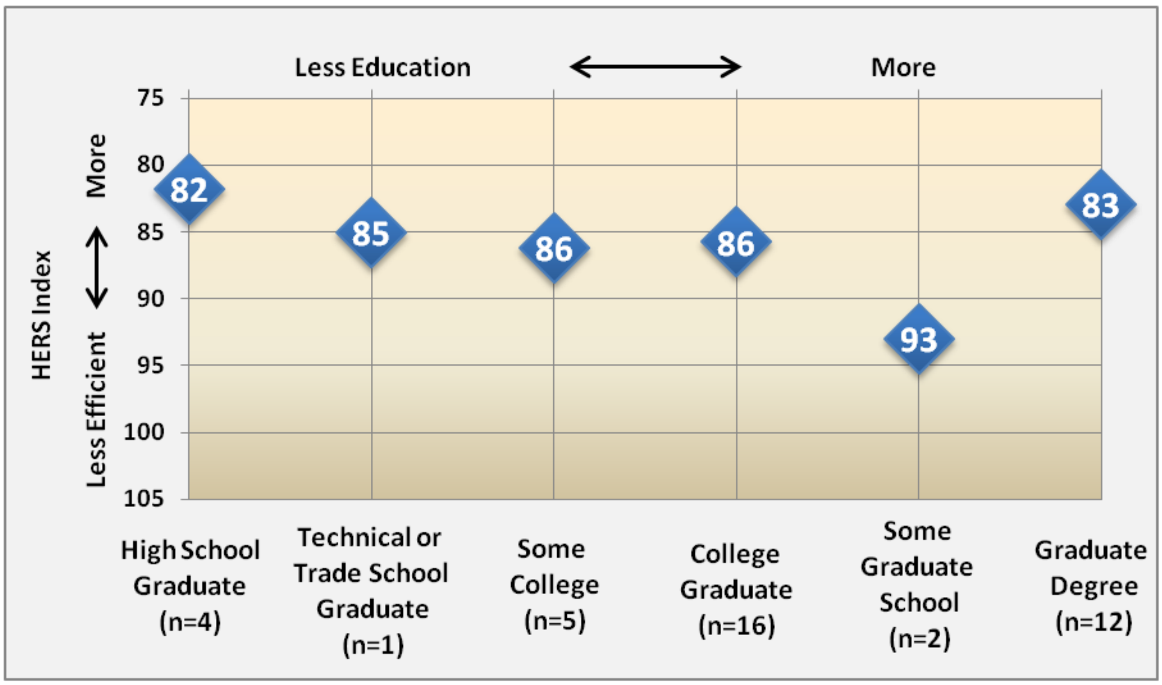


Figure 6-6 displays the average HERS rating for homeowners of each income level. Average HERS ratings vary from 102 (least efficient) for homeowners with annual incomes less than $50,000, to 76 (most efficient) for homeowners with annual incomes greater than $150,000. Figure 6-6 points to a positive relationship between income and energy efficiency. However, in interpreting this figure, it is important to keep the small sample sizes in mind.

Figure 6-6: Homeowner Income by Average HERS Rating

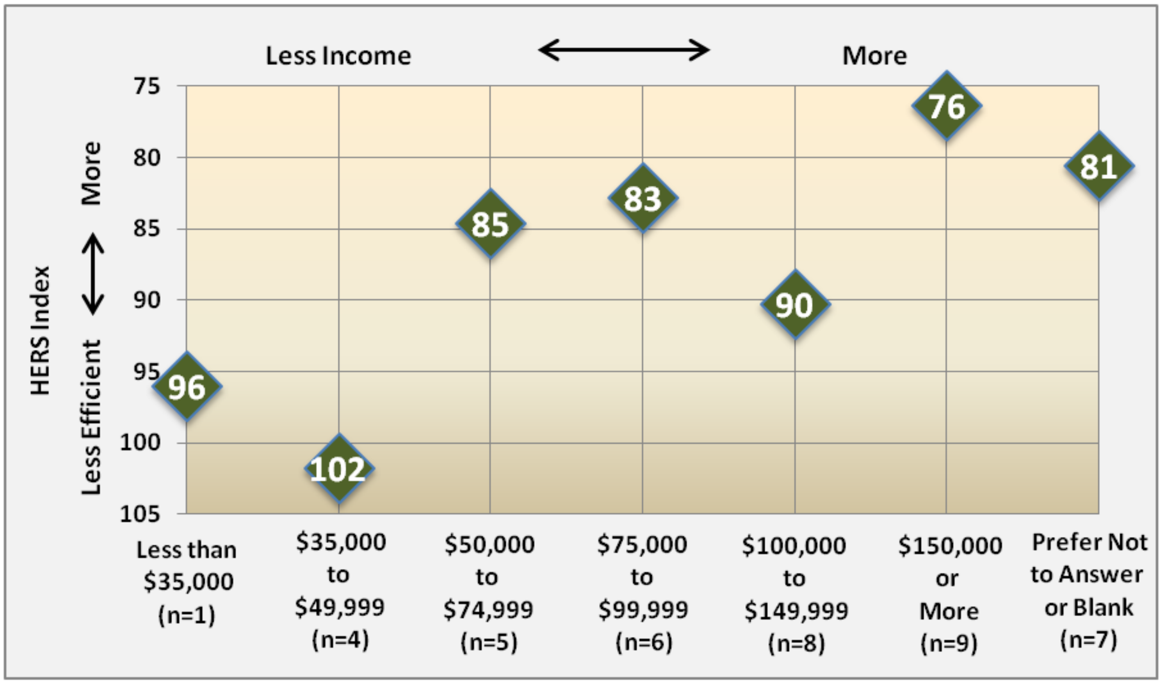
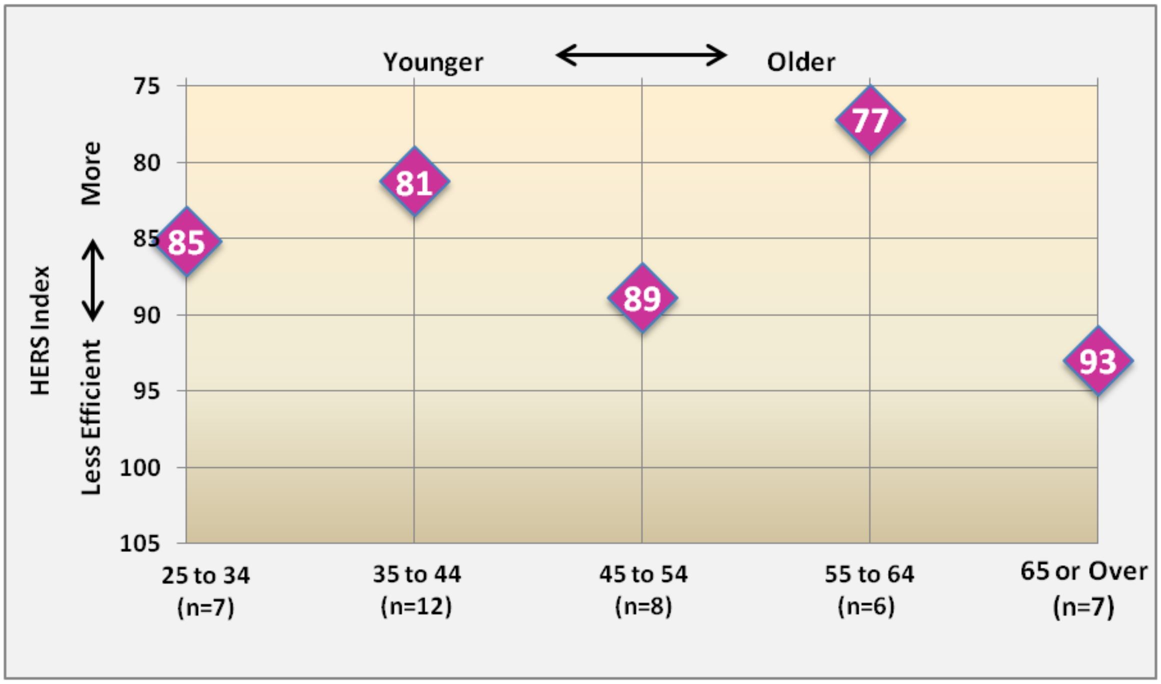


Figure 6-7 displays the average HERS rating for homeowners of each age group. Homeowners aged 55-64 have, on average, the most energy-efficient homes (HERS 77), while those 65 and over have the least efficient homes (HERS 93). The average HERS rating for the most populous age group (35 to 44) is 81, which is four index points lower (more energy efficient) than the average HERS rating of 85 across all 40 homes. As with homeowner education, there does not appear to be a clear relationship between average HERS rating and homeowner age.

Figure 6-7: Homeowner Age by Average HERS Rating



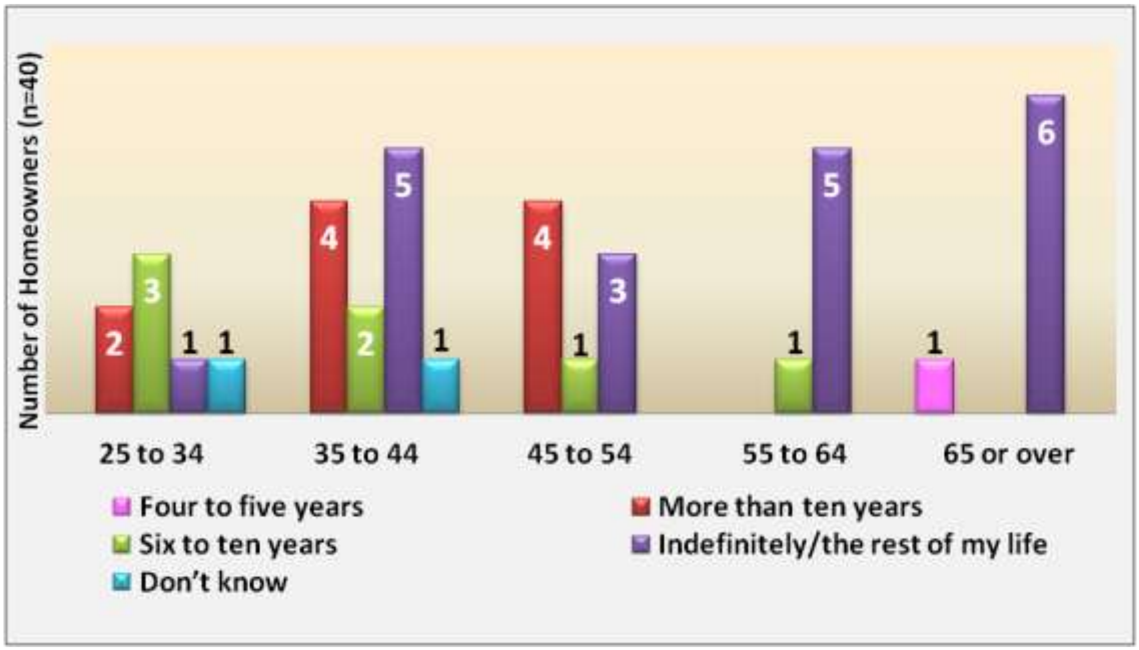
Only two of the 40 homeowners (5%) said that this was their first time buying a home. As shown in Table 6-2, the majority of homeowners (75%) plan to stay in their new home for at least ten years, and half of the homeowners plan to stay in their new home indefinitely.

Table 6-2: First Time Buyer and Expected Duration in New Home

First-Time Home Buyer? (n=40)	
Already owned home	90%
First-time home buyer	5%
Don't know or prefer not to answer	5%
How Long Do You Expect to Stay in Your New Home? (n=40)	
Four to five years	3%
Six to ten years	18%
More than ten years	25%
Indefinitely/the rest of my life	50%
Don't know	5%

Figure 6-8 displays how long homeowners plan to stay in their new home by their age categories. As shown, some homeowners within each age category report planning to stay in their new home indefinitely, although homeowners aged 65 and over are most likely to expect to stay in their new home indefinitely. Likewise, homeowners in the 25 to 34 age category are most likely to report planning to stay in their new home for fewer than ten years.

Figure 6-8: Homeowner Age by Expected Duration in New Home

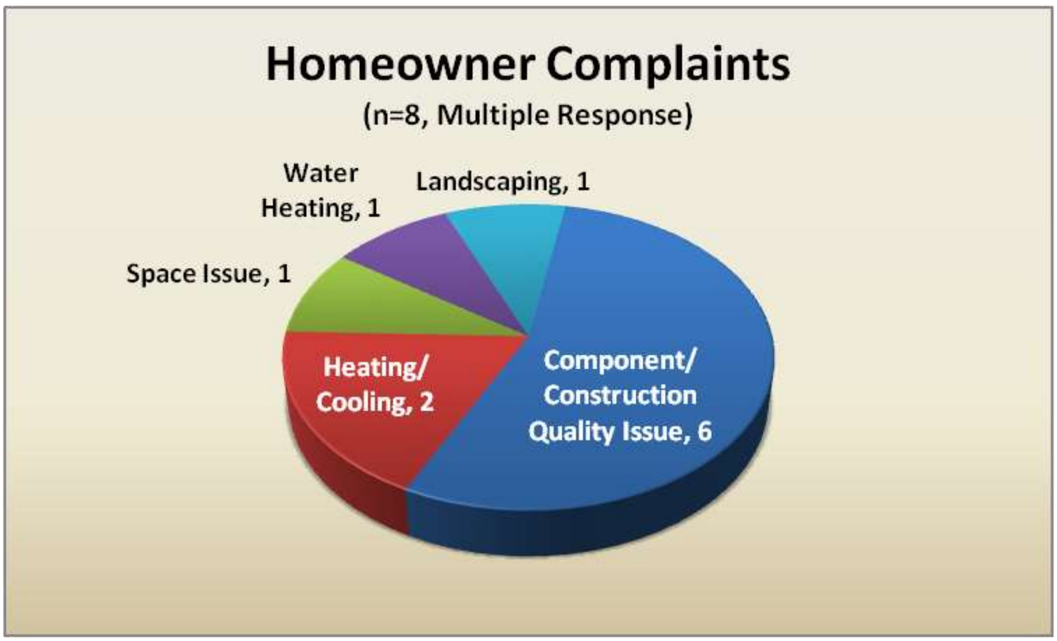


6.3 Comfort and Complaints

Homeowners were asked to describe the comfort of their home by indicating if it was "very comfortable," "somewhat comfortable," "somewhat uncomfortable," or "very uncomfortable." Most homeowners (90%) said their home is very comfortable; 10% said their home is somewhat comfortable.

Next, homeowners were given the opportunity to provide comments about the comfort of their new home and to describe any complaints they have about the home. Eight homeowners (or one-fifth of the homeowners) described a total of 11 complaints about their homes. Homeowners who said their home is very comfortable were actually more likely to mention a complaint than those who described their home as somewhat comfortable – eight of the eleven complaints were submitted by homeowners describing their home as very comfortable. Figure 6-9 displays the types of complaints submitted by homeowners and the number of complaints within each category. The majority of homeowner complaints pertain to the quality of specific components in the home and/or general construction quality. For example, one homeowner complained about a leak in the home, one homeowner complained about the windows, and another homeowner mentioned four separate complaints regarding various component and construction quality issues. The second most commonly mentioned type of complaint pertains to heating and cooling issues, including one compliant that the radiant heating system does not respond to changes to the temperature setting, and a complaint that the home is uncomfortable without central air conditioning, which the homeowner chose not to install due to the expense of installing it. Each of the homeowners who submitted heating/cooling complaints have homes with HERs ratings that are more energy efficient than the average HERs rating of 85 across all 40 homes: the homeowner who complained about the radiant heating system has a HERs rating of 68, and the homeowner who complained about the lack of central air conditioning has a HERs rating of 83. One homeowner each complained that the home is "a little small," that the hot water runs out, and that the landscaping is dissatisfactory.

Figure 6-9: Homeowner Complaints about New Home



6.4 Discussed Energy Efficiency with Builder or Sales Agent

Three-quarters (75%) of homeowners said their builder or sales agent talked to them about energy efficiency or the benefits of energy-efficient windows, heating and cooling equipment, insulation, etc.[20] Owners of custom homes were slightly more likely than owners of spec homes to say that their builder or sales agent talked about energy efficiency—79% of custom homeowners compared to 73% of spec homeowners. Over one-half (25 or 63%) of homeowners said they asked their builder or the sales agent about energy efficiency. Table 6-3 shows that almost one-third (30%) of homeowners who said that their builder or sales agent did not talk to them about energy efficiency, or they do not remember, said they asked about energy efficiency. In addition, most (73%) homeowners who said their builder or sales agent talked to them about energy efficiency also said they asked about energy efficiency.

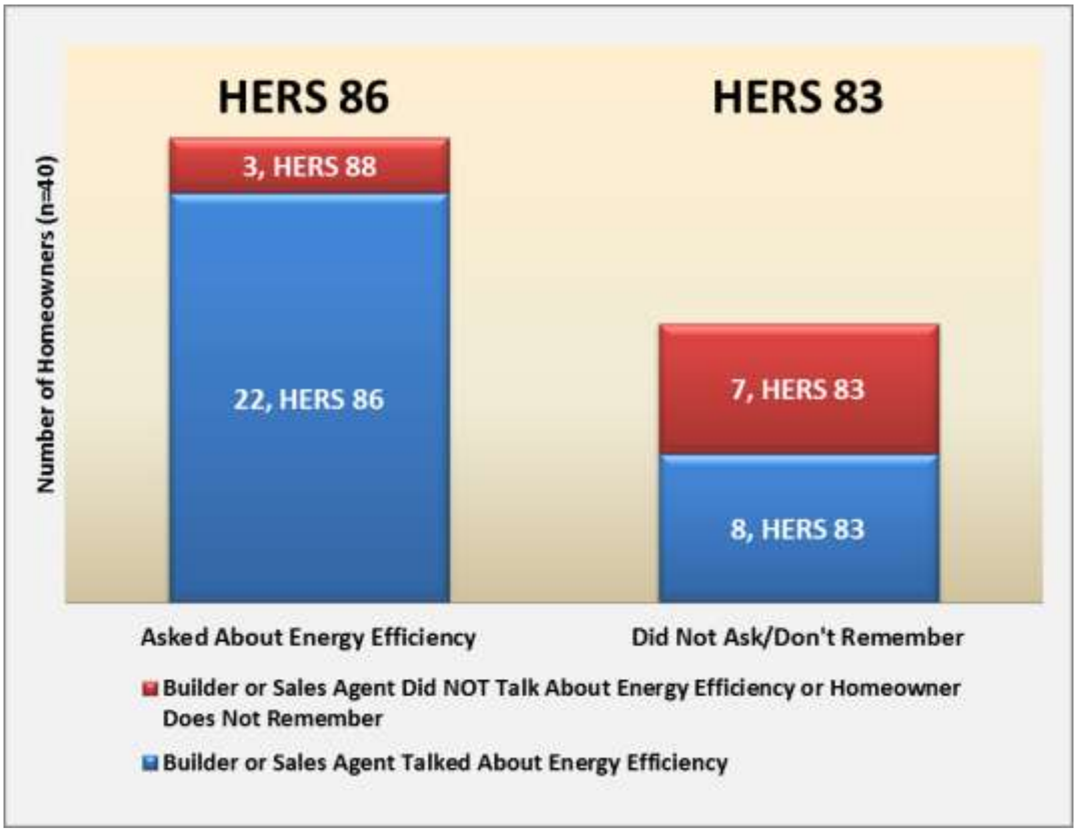
Table 6-3: Homeowners Who Discussed Energy Efficiency

	Number (%) of Homeowners	Number of Homeowners Who Asked About Energy Efficiency	Percent of Homeowners Who Asked About Energy Efficiency
Builder or Sales Agent Talked About Energy Efficiency (Includes homeowner/builders)	30 (75%)	22	73%
Builder or Sales Agent Did NOT Talk About Energy Efficiency or Homeowner Does Not Remember	10 (25%)	3	30%
Total Homeowners:	40	25	63%

[20] Homeowners who are also the builder/general contractor did not respond consistently to questions about whether or not their builder or sales agent talked to them about energy efficiency and whether or not they asked their builder or sales agent about energy efficiency. Some of these homeowners simply identified themselves as the builder/general contractor, some said they do not remember or left the question blank, and some said their builder talked to them about energy efficiency and/or that they asked their builder or sales agent about energy efficiency. It seems reasonable to assume that those who identified themselves as the builder/general contractor considered energy efficiency in their role as builder—several of the homeowners who were also the builder/general contractor commented that this was the case. Therefore homeowners who identified themselves as the builder/general contractor are counted as homeowners who say they talked to their builders or sales agents about energy efficiency or asked about energy efficiency.

Figure 6-10 shows that homeowners who did not ask their builder or sales agent about energy efficiency actually ended up with more energy efficient homes than those who did. The average HERS rating for homeowners that asked their builder or sales agent about energy efficiency (including all five owner/builders) is 86. In comparison, the average HERS rating for homeowners that did not ask about energy efficiency is 83, which is three index points lower (more energy efficient) than the average HERS rating for homeowners who asked about energy efficiency. Bearing in mind that these results are based on a small sample size, they indicate that asking the builder or sales agent about energy efficiency does not necessarily increase the likelihood getting an energy-efficient home.

Figure 6-10: Asked About Energy Efficiency by Average HERS Rating

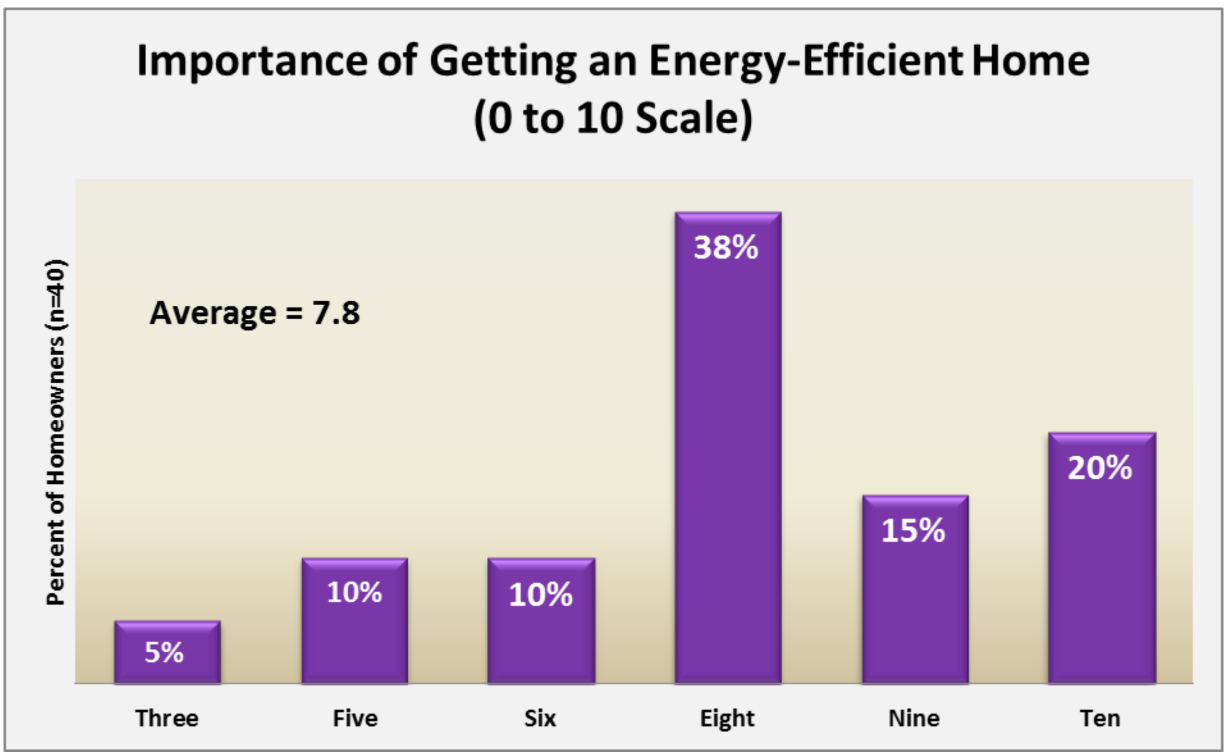


6.5 Importance of Getting an Energy-Efficient Home

Most homeowners reported that getting an energy-efficient home was relatively important in their decision to buy or build their home. However, homeowners who assigned a high importance rating to energy efficiency did not necessarily get energy-efficient homes. There are many possible explanations for this, including that homeowners are not adept at recognizing the factors that influence a home's energy efficiency. Another possible explanation is that some owners may have started out wanting the most energy-efficient options, but when budget limitations came into play the first things to go were the less visible energy-efficient options in favor of high-end appearance options such as granite countertops. It may also be that some owners said energy efficiency was important only because they were participating in a program to assess the energy efficiency of their home and felt they should say energy efficiency was important.

Using a scale of zero (one of the least important features) to ten (one of the most important features), homeowners rated the importance of getting an energy-efficient home in their decision to buy or build their home. The average rating is 7.8. Figure 6-11 shows that very few homeowners rated energy efficiency below five, and nearly three-quarters (73%) rated energy efficiency eight or higher.

Figure 6-11: Importance of Getting an Energy-Efficient Home



Homeowners who discussed energy efficiency with their builder or sales agent were more likely to assign higher importance to getting an energy-efficient home. Figure 6-12 displays homeowners' ratings of the importance of getting an energy-efficient home by whether or not the homeowner talked with the builder or sales agent about energy efficiency. Over four-fifths (33) of the homeowners said that either their builder or sales agent talked to them about energy efficiency, or they asked their builder/sales agent about energy efficiency. The average rating for homeowners who said they talked to their builder or sales agent about energy efficiency is 8.3; the average rating for homeowners who said they did not talk to their builder/sales agent about energy efficiency is 5.6.

Figure 6-12: Importance of Getting an Energy-Efficient Home by Talked to Builder/Agent about Energy Efficiency

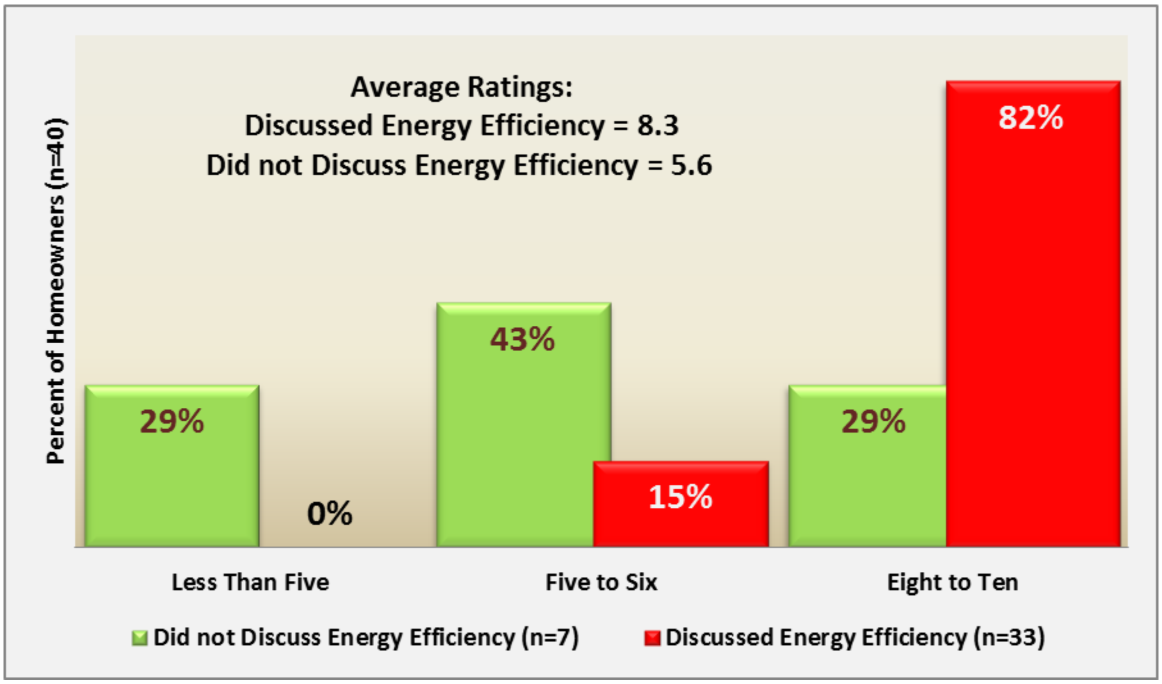
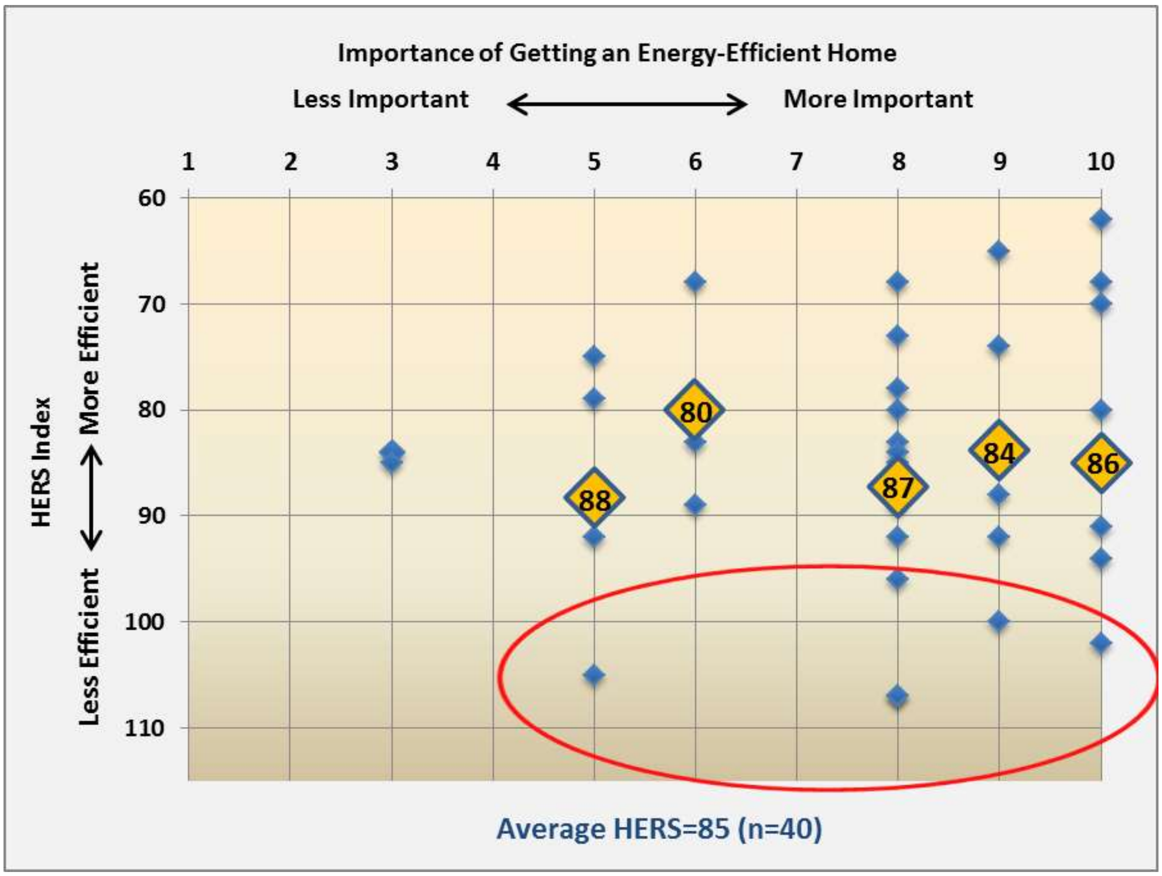


Figure 6-13 displays homeowners' ratings of the importance of getting an energy-efficient home by the homes' HERS ratings. Looking at the average HERS rating by importance rating shows that homeowners who assigned higher importance ratings did not necessarily get more efficient homes than those who assigned lower importance ratings. Homeowners who assigned the highest importance rating (10) to getting an energy-efficient home own homes that have an average HERS rating of 86. Homeowners who assigned a lower importance rating of 6 actually have homes that are, on average, more energy efficient (HERS 80) than those who assigned an importance rating of 10 (HERS 86). Moreover, looking at the 5 least efficient homes, four of the five homeowners assigned a high importance rating (8-10) to getting an energy-efficient home. The average HERS rating for all homeowners who assigned a high importance rating (8-10) to getting an energy-efficient home is 86, which is only one HERS index point lower (more efficient) than the average HERS rating of 85 across all 40 homes.

Figure 6-13: Importance of Getting an Energy-Efficient Home by HERS Rating

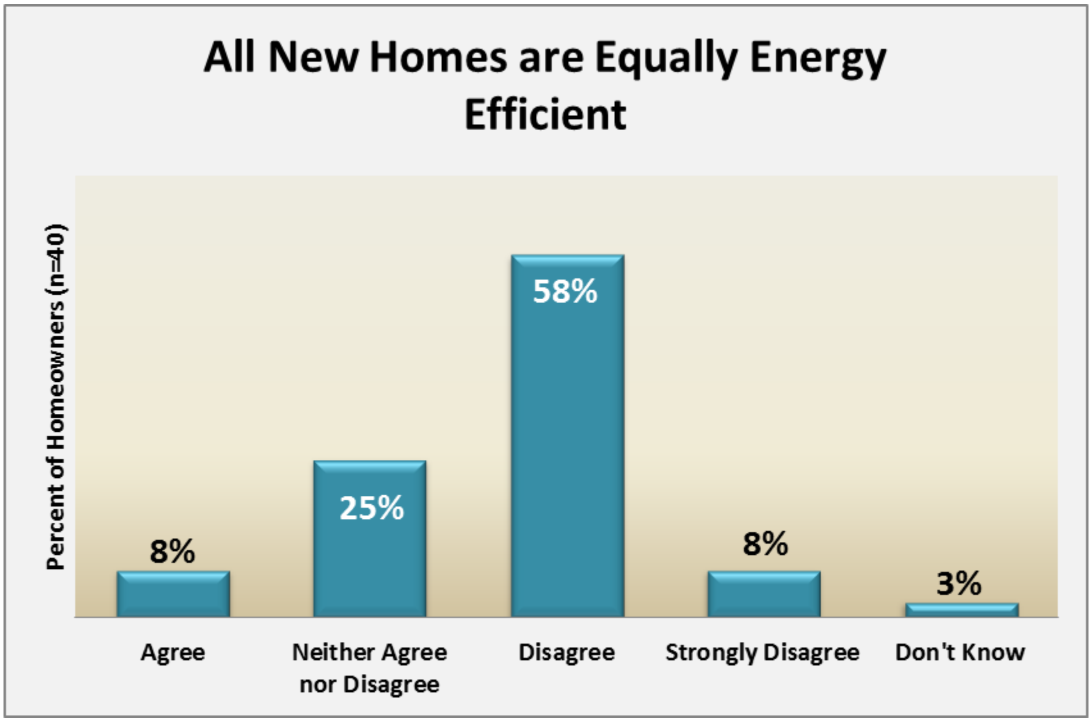


6.6 Homeowner Perception of Energy Efficiency of New Homes

Homeowners are generally aware that the energy efficiency of new homes varies from one home to another. However, many homeowners are not very good at assessing the energy efficiency of their homes. They may think any home with 2 x 6 framing is energy efficient and not consider the importance of air sealing and insulation levels or they may simply take the builder's word that a home is energy efficient. The following example looks at the most and least energy-efficient homes inspected, based on HERS ratings. Four of the five most energy-efficient homes, with HERS indices of 62 to 68, are custom homes; one is a spec home. Four of the five least energy-efficient homes, with HERS indices of 102 to 117, are spec homes; one is a custom home. As different as these two groups of homes are in terms of energy efficiency, many of the owners do not seem to be aware. Seven of the ten owners of these homes asked their builder or agent about energy efficiency and rated the importance of getting an energy-efficient home in their decision to buy or build their new home an 8, 9, or 10 on a scale of 0 (not important) to 10 (very important). Additionally, seven of the ten owners of these homes think their home is somewhat more energy efficient than other new homes—all five owners of the most efficient, and two of the five owners of the least efficient homes (one of whom who is an owner/builder). The owner of the least efficient of all 40 homes thinks his home is much more efficient than other new homes.

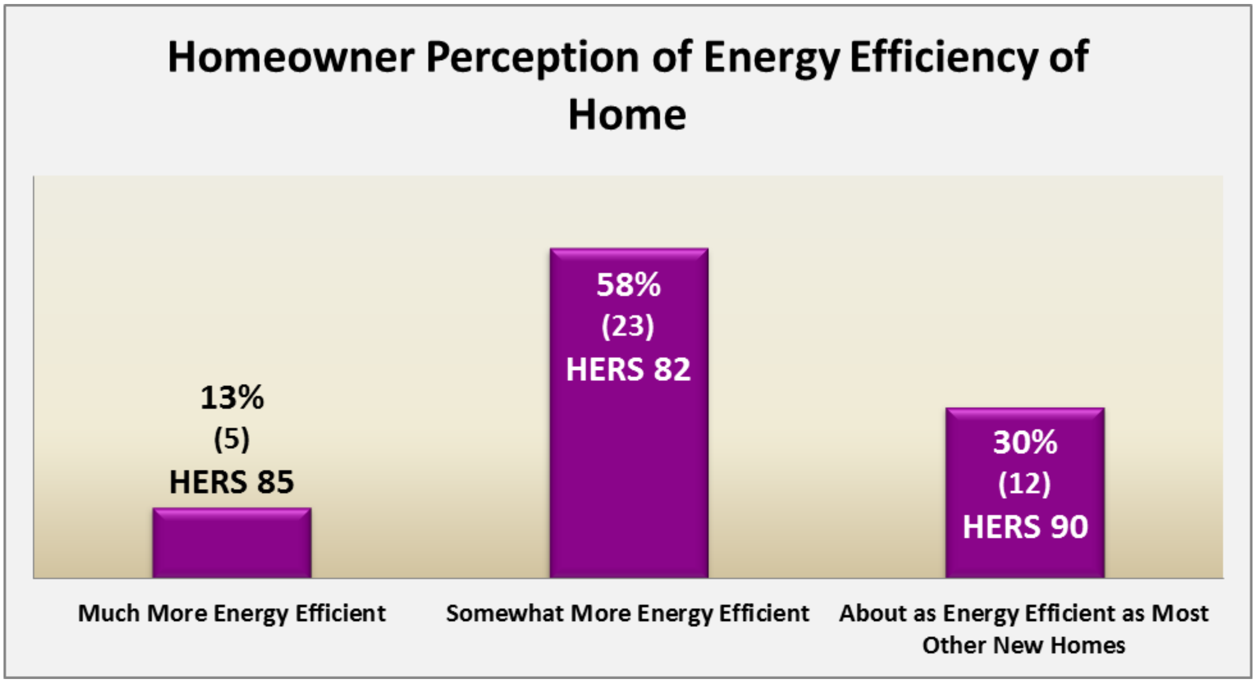
Homeowners were asked to indicate the extent to which they agree with the statement "all new homes are equally energy efficient." Figure 6-14 shows that the majority of homeowners (66%) disagree with this statement.

Figure 6-14: All New Homes are Equally Energy Efficient



Homeowners were asked how energy efficient they think their home is compared to other new homes. The answer choices were "much more energy efficient," "somewhat more energy efficient," "about as energy efficient," "somewhat less energy efficient," and "much less energy efficient." None of the homeowners think that their home is less energy efficient than other new homes. Figure 6-15 shows that most homeowners think their home is somewhat more energy efficient than other new homes (58%). As a group, these homeowners have homes that are, on average, three HERS index points lower (more efficient) than the sample average of 85. On average, homeowners who believe their home is about as efficient or much more energy efficient than other new homes tend to overestimate the energy efficiency of their homes. Homeowners reporting that their home is about as efficient as other new homes have an average HERS rating of 90, which is 5 HERS index points higher (less efficient) than the sample average of 85. Homeowners reporting that their home is much more energy efficient than other new homes have an average HERS rating of 85, which is equal to the sample average.

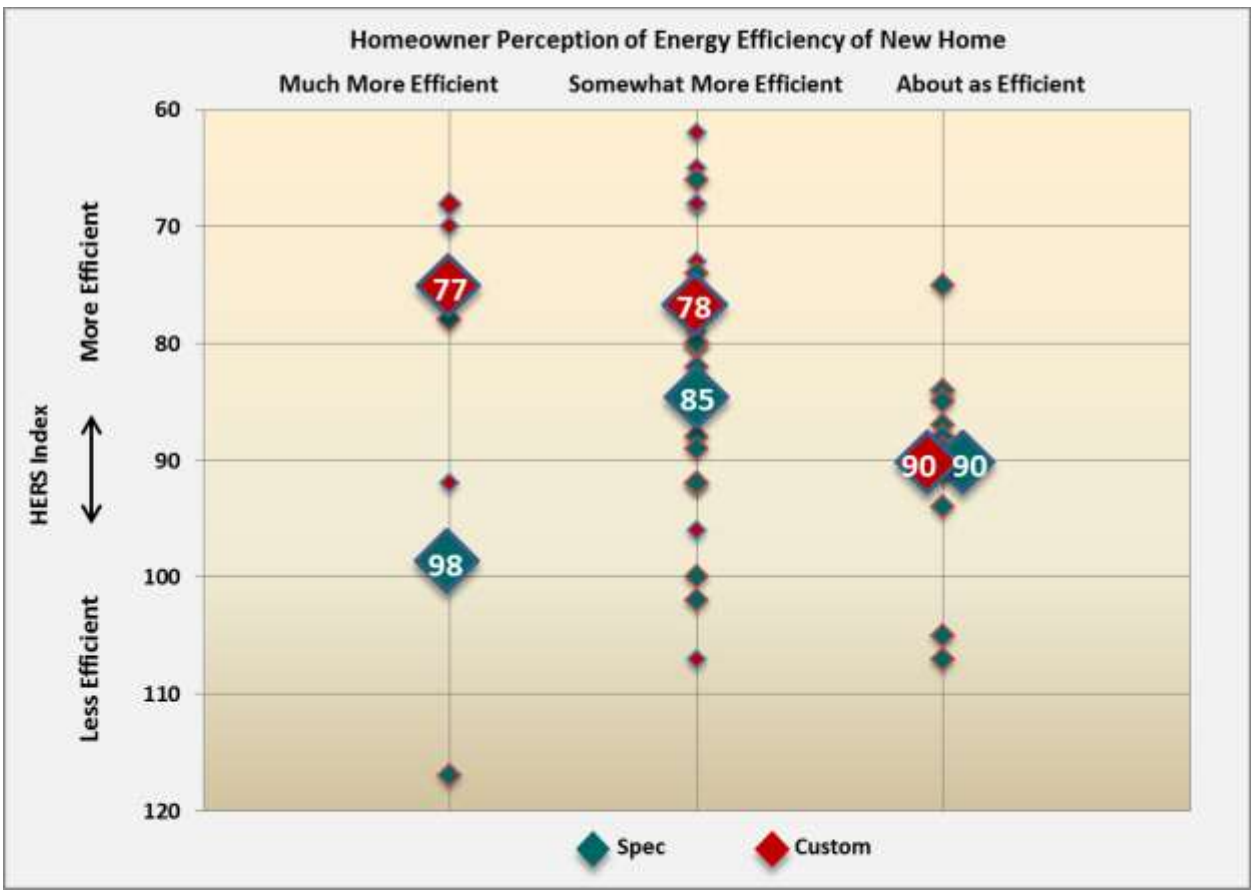
Figure 6-15: Homeowner Perception of Energy Efficiency of Home Compared to Other New Homes



Because custom homeowners initiate the home-building process, they are more involved in energy-efficiency related building decisions than spec homeowners and are generally better at assessing the energy efficiency of their homes. Custom homeowners were more likely than spec homeowners to say that their home is more efficient than other new homes—86% of custom homeowners said that their home is somewhat or much more efficient than other new homes compared to 62% of spec homeowners. In fact, the custom homeowners generally do have more energy-efficient homes than the spec homeowners—the average HERS rating among the custom homes is 79 (n=14), as compared to an average of 88 among the spec homes (n=26).

Figure 6-16 displays homeowners' perceptions of the energy efficiency of their homes by the homes' HERS ratings. The average HERS rating among custom homeowners who believe that their home is much more energy efficient than other new homes is 77, which is eight index points lower (more efficient) than the sample average HERS rating of 85. Two spec homeowners believe their home is much more efficient than other new homes—one of them owns a home that is more efficient than the sample average of 85 (HERS 78), but the other actually owns the least efficient of all 40 homes (HERS 117). The average HERS rating among custom homeowners who believe that their home is somewhat more energy efficient than other new homes is 78, which is seven index points lower (more efficient) than the sample average HERS rating of 85. On the other hand, spec homeowners who believe that their home is somewhat more energy efficient than other new homes have homes that are, on average, HERS 85, which is equal to the average HERS rating across all 40 homes. The average HERS rating among spec and custom homeowners alike who believe that their home is about as energy efficient as most other new homes is 90.

Figure 6-16: Homeowner Perception of Energy Efficiency of Home by HERS Rating

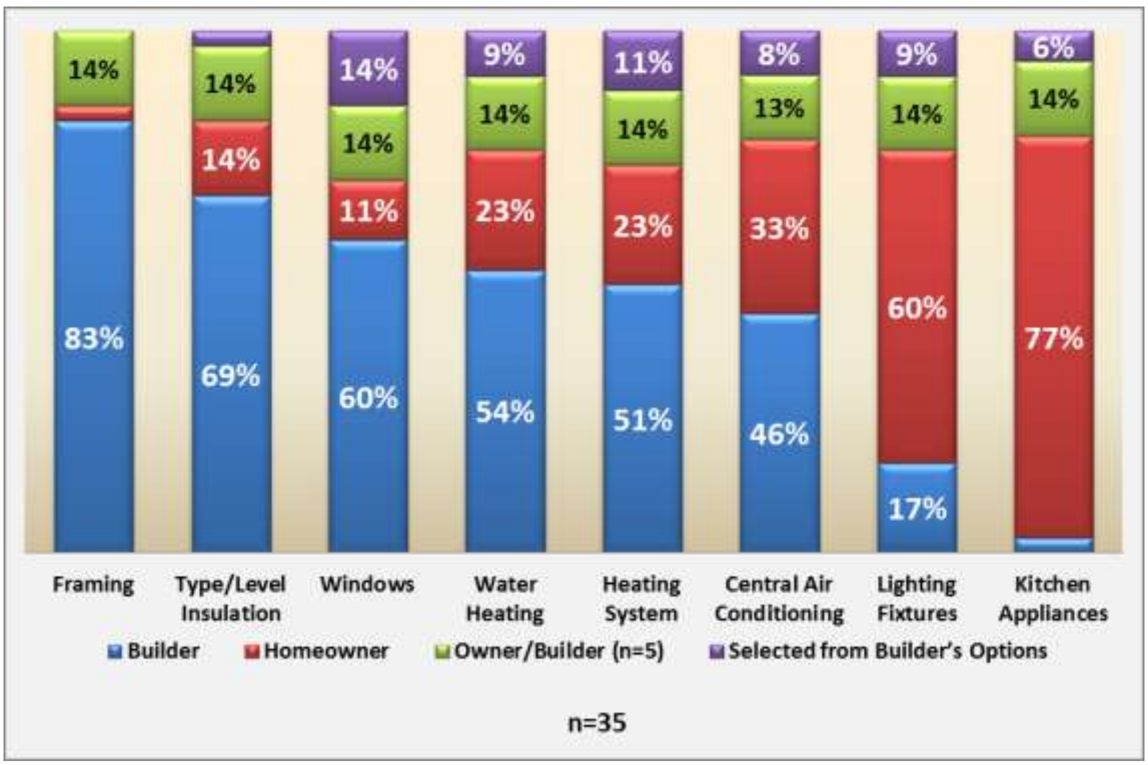


Over one-half (23) of the homeowners commented on why they believe their home is more energy efficient, or about as energy efficient, as other new homes. Homeowners who said their home is about as energy efficient as most other new homes generally mentioned that this is just an assumption and/or that their home is built to code. Most homeowners who provided an explanation as to why they believe their home is more energy efficient than other new homes mentioned specific energy-efficient components, including appliances, windows, insulation, and framing.

6.7 Homeowner Awareness of Equipment and Building Components

Homeowners who had the opportunity to choose various options for their home (those who had a custom home built or purchased a spec home before it was completed) were asked to indicate who was responsible for selecting numerous energy efficiency related components in their homes. Thirty-five of the 40 homeowners indicated that they had the opportunity to choose various options for their home. Figure 6-17 shows that builders are most likely to specify framing, insulation, windows, water heaters, and heating and cooling equipment, while homeowners are most likely to specify lighting fixtures and kitchen appliances. Homeowners who built or acted as the general contractor for their home are characterized as owner/builders in Figure 6-17, and in the majority of cases these homeowners say they made all the decisions.

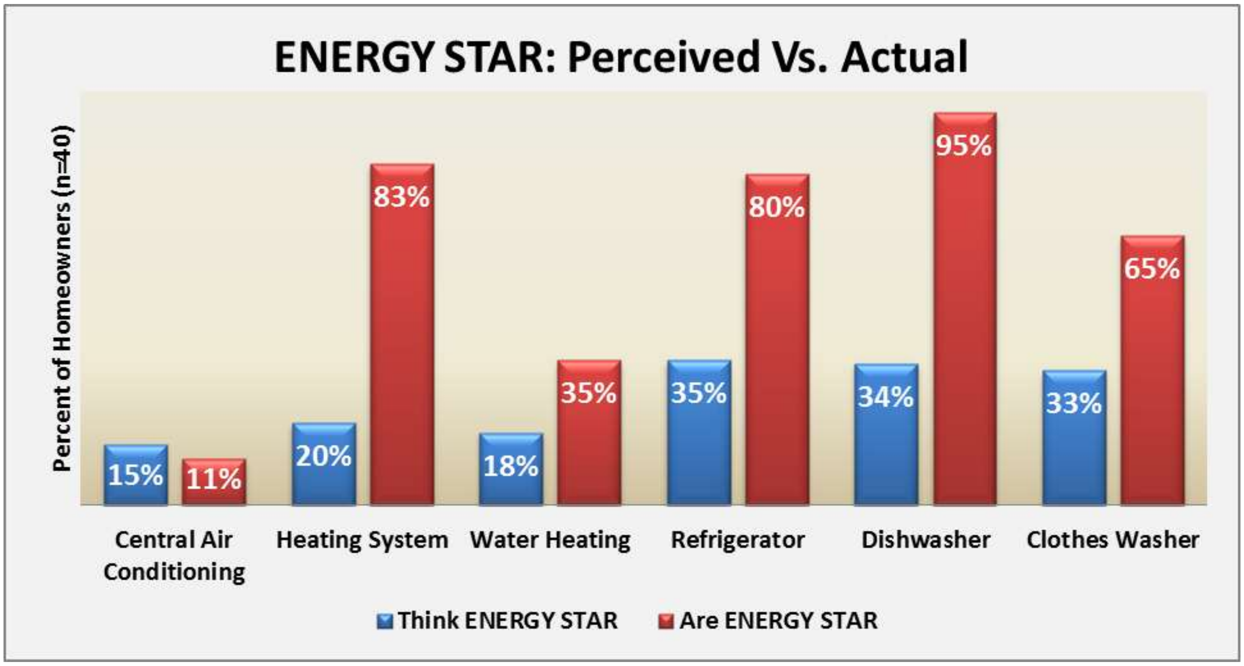
Figure 6-17: Who Specified Building Components



*Percentages for central air conditioning are percentages of homes with central air conditioning.

In many cases, homeowners are not aware that they own ENERGY STAR qualified components and appliances. Homeowners were asked to indicate whether certain components in their homes are ENERGY STAR labeled. Auditors noted whether the ENERGY STAR logo was present on these components during the audit, and recorded the model numbers which were later used to cross reference ENERGY STAR status from the Environmental Protection Agency (EPA) ENERGY STAR qualified products databases. Figure 6-18 displays the percentage of homeowners who think a component of their home is ENERGY STAR, and the percentage of homes where the component really is ENERGY STAR. Fewer than one-quarter of the homeowners who have ENERGY STAR heating systems are aware that their heating systems are ENERGY STAR qualified. One-half or fewer of the homeowners who have ENERGY STAR clothes washers, water heaters, refrigerators, and dishwashers are aware that they have ENERGY STAR appliances. Similar results were observed in the 2011 Massachusetts single-family residential new construction homeowner survey: for all components except for central air conditioning, fewer than one-half of the Massachusetts homeowners who had ENERGY STAR components were aware that they were ENERGY STAR qualified.[21]

Figure 6-18: ENERGY STAR Components – Perceived versus Actual



*Percentages for central air conditioning and dishwashers are percentages of homes with central air conditioning and dishwashers. Percentages for water heaters are percentages of ENERGY STAR eligible water heaters (gas instantaneous or storage) that qualify under either current ENERGY STAR criteria or ENERGY STAR criteria ending 8/31/2010.

[21] Massachusetts 2011 Baseline Study of Single-family Residential New Construction, Draft Report, Prepared for the Massachusetts Program Administrators by NMR Group, Inc., KEMA, Inc., The Cadmus Group, and Dorothy Conant. May 2012.

6.8 Awareness of ENERGY STAR Homes

Nearly three-quarters (73%) of homeowners said that they had seen or heard of a newly constructed home being referred to as an ENERGY STAR Home, including three of the five owners who acted as the builder or general contractor for their new home. However, only one in ten homeowners (10%) said that their builder or agent brought up the subject of ENERGY STAR Homes, indicating that builders and real estate agents are not a primary source of program awareness. Almost one in five homeowners (18%) said that they asked their builder or agent about ENERGY STAR Homes while making plans for building or buying a home. (Table 6-4)

Table 6-4: Homeowner Awareness of ENERGY STAR Homes

n=40	Heard of ENERGY STAR Homes?	Builder/Agent Talked About ENERGY STAR Homes	Asked About ENERGY STAR Homes
Yes	73%	10%	18%
No	25%	60%	60%
Don't Know/Blank	3%	30%	23%

*Percentages may not total 100% due to rounding.

Survey findings suggest that making potential home buyers aware of ENERGY STAR homes is not enough to get them to act on that awareness when they look for a home or a builder to build a custom home. Only 7 of the 29 owners (24%) who said they had seen or heard of a newly constructed home being referred to as an ENERGY STAR home said they asked their builder or sales agent about ENERGY STAR homes.

7 Building Envelope

This section addresses wall, ceiling, floor, slab, foundation wall and rim/band joist insulation and windows, doors and sunspaces.

7.1 Wall Insulation

Auditors recorded insulation and framing information for all walls on the thermal boundary of homes. This includes conditioned/ambient, conditioned/garage, conditioned/unconditioned basement, and conditioned/attic walls. Information was also recorded for adiabatic walls (walls shared with an adjoining housing unit) and unconditioned basement/garage walls. Auditors described how each wall was framed and the type, R-value and grade of the insulation installed.

Table 7-1 through Table 7-6 show the characteristics of each wall type for all inspected homes, spec homes, custom homes and weighted data reflecting the mix of single-family spec and custom housing in the 2011 Program.

Fiberglass batt insulation is clearly dominant—weighted percentages for walls insulated with only fiberglass batt insulation are 84% or higher for every wall category. Weighted average insulation levels range from R-11.4 in conditioned/unconditioned basement walls to R-19.0 in adiabatic and unconditioned basement/garage walls. Weighted framing data show 2 x 6 16 inch-on-center framing is predominant in all wall types except conditioned/unconditioned basement and conditioned/attic walls, where 2 x 4 16 inch-on-center framing predominates. Weighted data show insulation is most likely to be verifiable in conditioned/attic walls and least likely in adiabatic walls. Auditors assigned a Grade I rating (the best rating) to insulation installation in only a few homes. No fiberglass batt insulation installations received a Grade I. Both raw and weighted data show Grade II installations are the most common for conditioned ambient and conditioned/garage walls. Grade III installations are the most common for conditioned/attic and adiabatic walls. Weighted results for conditioned/ambient walls are 10% Grade I, 71% Grade II, and 19% Grade III.

Table 7-1: Characteristics of Conditioned/Ambient Walls

Conditioned/ Ambient Walls	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=16)	Weighted (Spec/ Custom)
Average R-value	18.3	17.5	19.6	17.7
Framing				
2 x 4 16" On Center	9 (23%)	8 (31%)*	1 (7%)*	28%
2 x 6 16" On Center	30 (75%)	18 (69%)	12 (86%)	71%
2 x 6 x 16" & 2 x 4 x 16" On Center	1 (3%)	0 (0%)	1 (7%)	1%
Insulation Verified, Installation Grade and Type				
Insulation Verified	8 (20%)	4 (15%)	4 (29%)	17%
Grade I Installation	6 (15%)	2 (8%)	4 (29%)	10%
Grade II Installation	27 (68%)	19 (73%)	8 (57%)	71%
Grade III Installation	7 (18%)	5 (19%)	2 (14%)	19%
Only Fiberglass Batts	34 (85%)	24 (92%)	10 (71%)	90%
Spray Foam	5 (13%)	2 (8%)	3 (21%)	9%
Spray & Rigid Foam	1 (3%)	0 (0%)	1 (7%)	1%

* Significantly different at the 90% confidence level.

Table 7-2: Characteristics of Conditioned/Garage Walls

Conditioned/ Garage Walls	All Homes (n=26)	Spec Homes (n=19)	Custom Homes (n=7)	Weighted (Spec/ Custom)
Average R-value	17.3	16.7	19.0	17.0
Framing				
2 x 4 16" On Center	11 (42%)	9 (47%)	2 (29%)	45%
2 x 6 16" On Center	15 (58%)	10 (53%)	5 (71%)	55%
Insulation Verified, Installation Grade and Type				
Insulation Verified	5 (19%)	3 (16%)	2 (29%)	17%
Grade I Installation	3 (12%)	1 (5%)	2 (29%)	8%
Grade II Installation	19 (73%)	14 (74%)	5 (71%)	73%
Grade III Installation	4 (15%)	4 (21%)*	0 (0%)*	19%
Only Fiberglass Batts	23 (88%)	18 (95%)	5 (71%)	92%
Spray Foam	3 (12%)	1 (5%)	2 (29%)	8%

* Significantly different at the 90% confidence level.

Table 7-3: Characteristics of Conditioned/Attic Walls

Conditioned/Attic R-value	All Homes (n=10)	Spec Homes (n=6)	Custom Homes (n=4)	Weighted (Spec/ Custom)
Average R-value	15.6	17.0	13.5	16.7
Framing				
2 x 4 16" On Center	6 (60%)	3 (50%)	3 (75%)	53%
2 x 6 16" On Center	4 (40%)	3 (50%)	1 (25%)	48%
Insulation Verified, Installation Grade and Type				
Insulation Verified	6 (60%)	3 (50%)	3 (75%)	53%
Grade I Installation	0 (0%)	0 (0%)	0 (0%)	0%
Grade II Installation	4 (40%)	3 (50%)	1 (25%)	48%
Grade III Installation	6 (60%)	3 (50%)	3 (75%)	53%
Only Fiberglass Batts	10 (100%)	6 (100%)	4 (100%)	100%

Table 7-4: Characteristics of Conditioned/Unconditioned Basement Walls

Conditioned/Unconditioned Basement R-value	All Homes (n=10)	Spec Homes (n=7)	Custom Homes (n=3)	Weighted (Spec/ Custom)
Average R-value	11.8	11.1	13.3	11.4
Framing				
2 x 4 16" On Center	8 (80%)	6 (86%)	2 (67%)	84%
2 x 6 16" On Center	2 (20%)	1 (14%)	1 (33%)	16%
Insulation Verified, Installation Grade and Type				
Insulation Verified	2 (20%)	1 (14%)	1 (33%)	16%
Grade I Installation	1 (10%)	0 (0%)	1 (33%)	3%
Grade II Installation	5 (50%)	3 (43%)	2 (67%)	45%
Grade III Installation	3 (30%)	**3 (43%)***	**0 (0%)***	39%
n/a No Insulation	1 (10%)	1 (14%)	0 (0%)	13%
Only Fiberglass Batts	8 (80%)	6 (86%)	2 (67%)	84%
Spray Foam	1 (10%)	0 (0%)	1 (33%)	3%
No Insulation	1 (10%)	1 (14%)	0 (0%)	13%

* Significantly different at the 90% confidence level.

Table 7-5: Characteristics of Unconditioned Basement/Garage Walls

Unconditioned Basement/Garage Walls	All Homes (n=2)	Spec Homes (n=2)	Custom Homes (n=0)	Weighted (Spec/ Custom)
Average R-value	19.0	19.0	n/a	19.0
Framing				
2 x 6 16" On Center	2 (100%)	2 (100%)	n/a	100%
Insulation Verified, Installation Grade and Type				
Insulation Verified	1 (50%)	1 (50%)	n/a	50%
Grade II Installation	1 (50%)	1 (50%)	n/a	50%
Grade III Installation	1 (50%)	1 (50%)	n/a	50%
Only Fiberglass Batts	2 (100%)	2 (100%)	n/a	100%

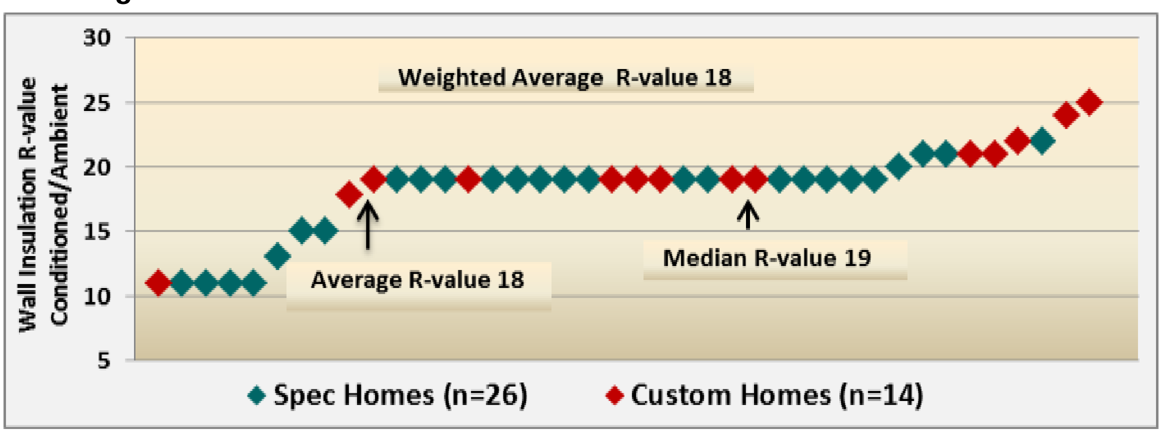
Table 7-6: Characteristics of Adiabatic Walls

Adiabatic Walls R-value	All Homes (n=2)	Spec Homes (n=2)	Custom Homes (n=0)	Weighted (Spec/ Custom)
Average R-value	19.0	19.0	n/a	19.0
Framing				
2 x 6 16" On Center	2 (100%)	2 (100%)	n/a	100%
Insulation Verified, Installation Grade and Type				
Insulation Verified	0 (0%)	0 (0%)	n/a	0%
Grade I Installation	0 (0%)	0 (0%)	n/a	0%
Grade II Installation	0 (0%)	0 (0%)	n/a	0%
Grade III Installation	2 (100%)	2 (100%)	n/a	100%
Only Fiberglass Batts	2 (100%)	2 (100%)	n/a	100%

7.1.1 Conditioned/Ambient Walls

Because of their greater importance in overall home energy efficiency, the remainder of this section focuses on the efficiency of conditioned/ambient walls. As reported above, the average recorded insulation level in conditioned/ambient walls is R-18.3 and the weighted average is R-17.7. Figure 7-1 graphs the individual recorded R-values in conditioned/ambient walls for all 40 inspected homes.

Figure 7-1: Recorded R-Value for Conditioned/Ambient Wall Insulation



As described earlier, fiberglass batts continue to be the insulation of choice and in a large majority of the 40 inspected homes (75%) conditioned/ambient wall framing is 2 x 6 studs 16 inch-on-center. Table 7-7 shows the average R-value is higher in custom homes (R-19.6) than in spec homes (R-17.5), but this difference is not significant at the 90% confidence level; the weighted average is R-17.7. With respect to prescriptive insulation requirements, 9 of the 40 inspected homes meet or exceed the 2009 IECC prescriptive compliance path requirement of R-20 conditioned/ambient wall insulation; the weighted percentage is 17%.

Table 7-7: Conditioned/Ambient Wall Insulation Statistics

Conditioned/Ambient Wall Statistics	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=16)	Weighted* (Spec/ Custom)
Minimum R-value	11.0	11.0	11.0	11.0
Maximum R-value	25.0	22.0	25.0	25.0
Average R-value	**18.3**	**17.5**	**19.6**	**17.7**
Median R-value	19.0	19.0	19.0	19.0
Comparison to 2009 IECC (R-20)				
Less Than R-20 or R-13+5	31 (78%)	22 (85%)	9 (64%)	83%
R-20 or R-13+5	1 (3%)	1 (4%)	0 (0%)	3%
More Than R-20 or R-13+5	8 (20%)	3 (12%)	5 (36%)	14%

*Only the average is weighted.

7.1.2 Who Specified Framing and Insulation

All 40 homeowners completed the on-site survey, but not all owners responded to all questions. Therefore, the numbers of responses on which presented results are based vary. The on-site homeowner survey asked who specified the framing and insulation. The choices were:

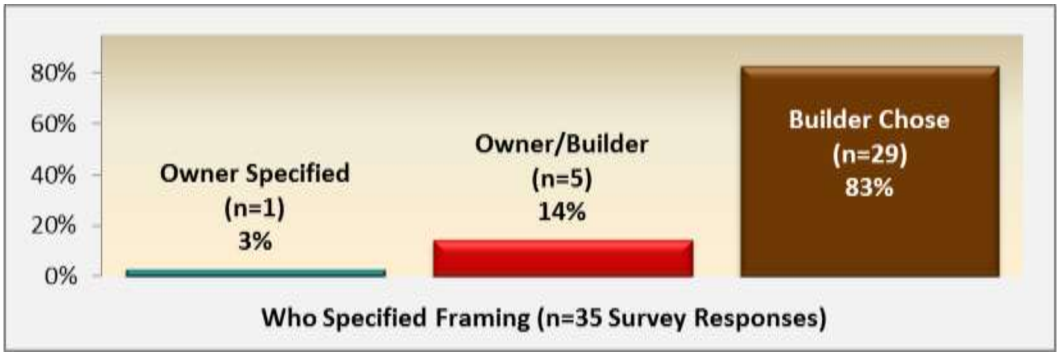
- I specified (Note that owners who are also the builder are treated as a separate category in this section.)
- Builder chose
- Selected from options offered by the builder
- Do not remember or do not know

Homeowners were not asked what type of framing was used or what type or level of insulation was installed. If they responded that they specified the insulation, they were asked, “Do you remember what you specified?” If they remembered, they were asked to check all options that applied; the two options were “Type of Insulation” and “Level of Insulation.”

Framing

Thirty-five owners responded to the question asking who specified the framing for their home. Figure 7-2 shows builders chose the type of framing for most of these homes (29 homes or 83%). Six owners, including five who built their own homes, say they specified the type of framing for their home.

Figure 7-2: Who Specified Framing



All but nine of the 40 inspected homes have 2 x 6 framing. Eight of the nine homes with 2 x 4 framing are spec homes and one is a custom home where the existing home was demolished and a new home built. Builders specified the framing in six of the nine homes with 2 x 4 framing, the owner specified the framing in one home, and the owners of two homes with 2 x 4 framing did not say who specified the framing.

Insulation

Thirty-five owners responded to the question asking who specified the type and/or level of insulation for their home. Figure 7-3 shows builders chose the type of insulation for most homes (69%). Nine of the ten owners who say they specified the insulation for their home, including four of the five owner/builders say they specified both the type and level of insulation.

Figure 7-3: Who Specified Insulation

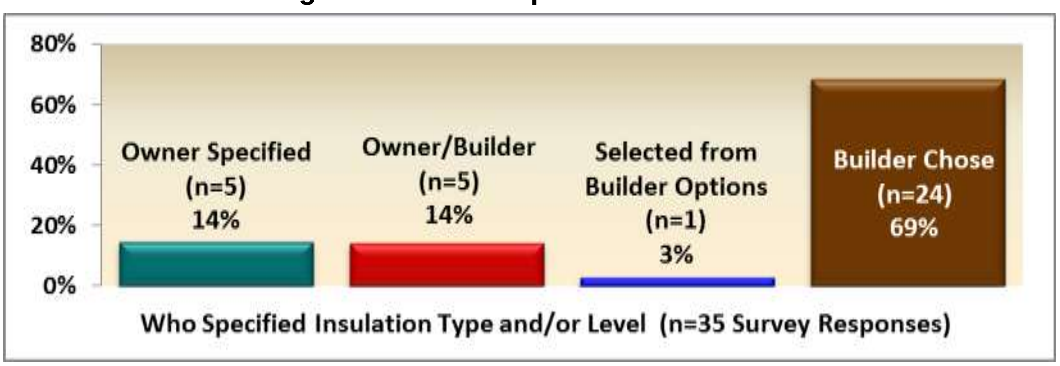


Figure 7-4 shows the average wall insulation R-value by who specified the insulation.[22] As shown, average R-values vary from R-16.4 to R-22.0 depending on who specified the insulation. The highest average R-values are for homes where the owner/builder specified the insulation and the one home where the owner selected from options offered by the builder. The average R-value in homes where the builder specified the insulation without input from the owner is R-18.4. The lowest average R-value of R-16.4 is for the five homes where the owners say they specified the insulation; four of these homes are spec homes with insulation R-values ranging from R-11 to R-19 and one is a custom home with R-22 insulation.

Figure 7-4: Average Wall Insulation R-value by Who Specified

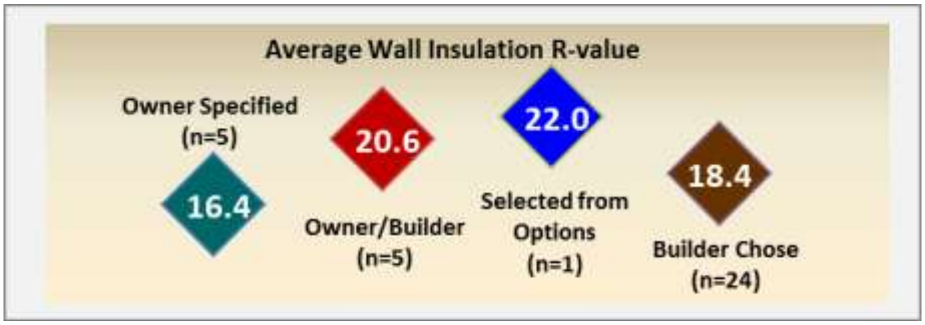
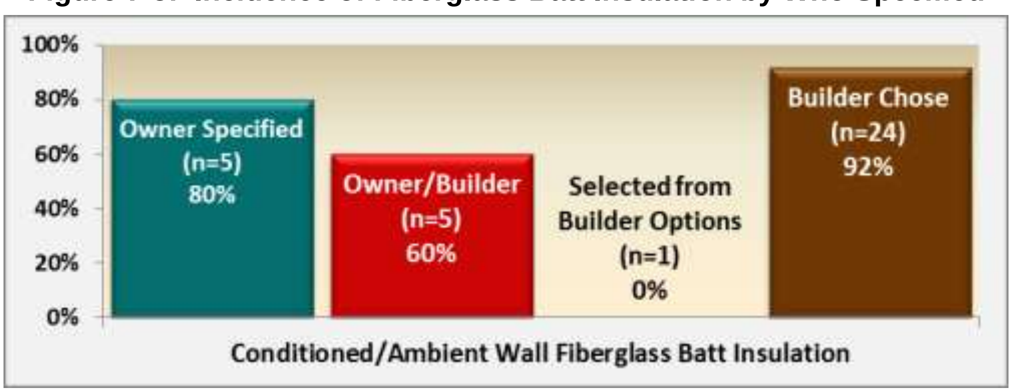


Figure 7-5 shows the incidence of fiberglass batt conditioned/ambient wall insulation by who specified the insulation. Clearly, fiberglass batt insulation is most common. The home of the one owner who selected from options offered by the builder has R-22 spray foam insulation. The home of one non-builder owner who specified the insulation also has R-22 spray foam insulation. Two of the owner/builder homes have spray foam insulation—one has R-21 and the other has R-25 insulation. Only two of the homes were the builder specified the insulation have something other than fiberglass batt insulation—one home as R-20 spray foam and one has R-24 using a combination of spray and rigid foam.

Figure 7-5: Incidence of Fiberglass Batt Insulation by Who Specified



[22] Owners were not asked what type or level of insulation was installed, nor were they asked specifically about wall insulation. Wall insulation R-values are used in Figure 7-4 because all homes had insulated conditioned/ambient walls.

Owners were asked to rate the energy efficiency of the type and the level of insulation in their homes. The choices were:

- Not Energy Efficient
- Average
- Very Energy Efficient
- ENERGY STAR Labeled
- Do Not Know

Figure 7-6 shows how owners perceive the energy efficiency of the type and level of insulation used in their home and Figure 7-7 shows the average conditioned/ambient wall R-value by how owners perceive the energy efficiency of the type of insulation and the level of insulation used in their home. As shown, most owners think both the type and level of insulation used in their home is average or very energy efficient. Both of the two owners who think the type and level of insulation in their homes is ENERGY STAR labeled have spray foam insulation. Of the two homes where the owners say they do not know how energy efficient the type or level of insulation is, one has fiberglass batt and one has spray foam insulation.

Figure 7-6: Perceived Energy Efficiency of Type and Level of Insulation

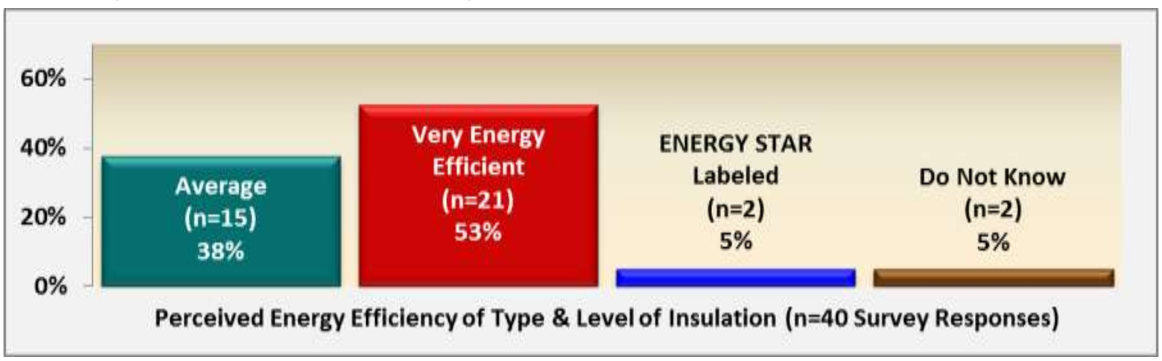
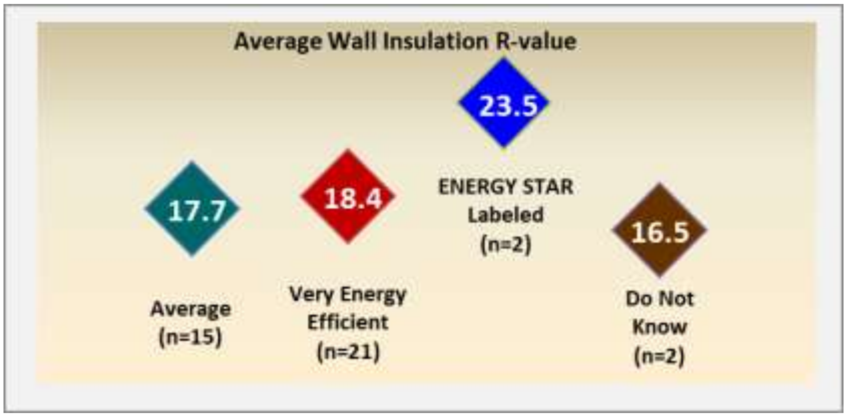


Figure 7-7 shows that average R-values vary from R-16.5 to R-23.5 depending on how energy efficient owners think the type and level of insulation installed in their home is. The average R-value is highest (R-23.5) in the two homes where the owners say the type and level of insulation installed is ENERGY STAR labeled; both of these homes have spray foam insulation. The average R-value is lowest (R-16.5) in the two homes where the owners say they do not know how energy efficient the type or level of insulation installed in their homes is; one home has R-13 fiberglass batt and one has R-20 spray foam insulation.

Figure 7-7: Average Wall Insulation R-value by Perceived Energy Efficiency of Type and Level of Insulation



7.2 Ceiling Insulation

Auditors reported data for flat and cathedral (vaulted) attic insulation; 35 inspected homes have flat ceiling areas and 19 have cathedral ceiling areas. Table 7-8 and Table 7-9 show the characteristics of flat and cathedral ceilings for all inspected homes, spec homes, custom homes and weighted data reflecting the mix of single-family spec and custom housing in the 2011 Program. Auditors were able to verify the insulation in flat ceilings more often than in cathedral ceilings: the weighted averages of verified insulation installations are 92% for flat and 59% for cathedral ceilings. Weighted average insulation levels are R-34.6 for flat ceilings and R-32.8 for cathedral ceilings. The most common framing for both flat and cathedral ceilings is 2 x 10 16 inch-on-center, followed by 2 x 8 16 inch-on-center. The weighted percentage of 2 x 10 and 2 x 8 16 inch-on-center framing combined is 48% for flat and 85% for cathedral ceilings.

Once again, fiberglass batt insulation dominates. Weighted results are 85% for both flat and cathedral ceilings. Grade I installations are reported for flat ceilings in four homes and for cathedral ceilings in five homes; none of the Grade I installations are for homes where only fiberglass batts were used.[23] Weighted results for flat ceilings are 9% Grade I, 65% Grade II and 25% Grade III and for cathedral ceilings 14% Grade I, 44% Grade II, and 42% Grade III.

Table 7-8: Flat Ceiling Characteristics

Flat Ceilings	All Homes (n=35)	Spec Homes (n=24)	Custom Homes (n=11)	Weighted (Spec/ Custom)
Average R-value	34.5	34.6	34.2	34.6
Framing				
2 x 4 x 16" On Center	4 (11%)	**4 (17%)***	**0 (0%)***	15%
2 x 4 x 24" On Center	2 (6%)	1 (4%)	1 (9%)	5%
2 x 6 x 16" On Center	3 (9%)	2 (8%)	1 (9%)	8%
2 x 8 x 16" On Center	6 (17%)	5 (21%)	1 (9%)	20%
2 x 10 x 16" On Center	12 (34%)	6 (25%)	6 (55%)	28%
2 x 10 x 24" On Center	2 (6%)	2 (8%)	0 (0%)	8%
2 x 12 x 24" On Center	1 (3%)	0 (0%)	1 (9%)	1%
Truss	5 (14%)	4 (17%)	1 (9%)	16%
Insulation Verified, Installation Grade and Type				
Insulation Verified	32 (91%)	22 (92%)	10 (91%)	92%
Grade I Installation	4 (11%)	2 (8%)	2 (18%)	9%
Grade II Installation	22 (63%)	16 (67%)	6 (55%)	65%
Grade III Installation	9 (26%)	6 (25%)	3 (27%)	25%
Only Fiberglass Batts	28 (80%)	21 (88%)	7 (64%)	85%
Blown-in Fiberglass	2 (6%)	2 (8%)	0 (0%)	8%
Cellulose	2 (6%)	1 (4%)	1 (9%)	5%
Spray Foam	3 (9%)	**0 (0%)***	**3 (27%)***	3%

* Significantly different at the 90% confidence level.

[23] Auditors typically rated a ceiling insulation installation as Grade I if the insulation was a blown-in product that filled the cavity with no compression or if the ceiling insulation was some form of spray foam.

Table 7-9: Cathedral Ceiling Characteristics

Cathedral Ceilings	All Homes (n=19)	Spec Homes (n=9)	Custom Homes (n=10)	Weighted (Spec/ Custom)
Average R-value	33.0	32.8	33.2	32.8
Framing				
2 x 6 x 16" On Center	1 (5%)	0 (0%)	1 (10%)	1%
2 x 8 x 16" On Center	3 (16%)	2 (22%)	1 (10%)	21%
2 x 8 x 24" On Center	1 (5%)	0 (0%)	1 (10%)	1%
2 x 10 x 16" On Center	10 (53%)	6 (67%)	4 (40%)	64%
2 x 10 x 16" On Center & SIPS	1 (5%)	0 (0%)	1 (10%)	1%
2 x 10 x 24" On Center	1 (5%)	1 (11%)	0 (0%)	10%
2 x 12 x 16" On Center	1 (5%)	0 (0%)	1 (10%)	1%
2 x 12 x 24" On Center	1 (5%)	0 (0%)	1 (10%)	1%
Insulation Verified, Installation Grade and Type				
Insulation Verified	14 (74%)	**5 (56%)***	**9 (90%)***	59%
Grade I Installation	5 (26%)	1 (11%)	4 (40%)	14%
Grade II Installation	8 (42%)	4 (44%)	4 (40%)	44%
Grade III Installation	6 (32%)	4 (44%)	2 (20%)	42%
Only Fiberglass Batts	13 (68%)	**8 (89%)***	**5 (50%)***	85%
Spray Foam	5 (26%)	1 (11%)	4 (40%)	14%
Spray Foam & SIPS	1 (5%)	0 (0%)	1 (10%)	1%

* Significantly different at the 90% confidence level.

Table 7-10 and Table 7-11 show weighted average insulation levels of R-34.6 for flat ceilings and R-32.8 for cathedral ceilings. Reported flat ceiling insulation levels range from R-19 to R-57 in spec homes and from R-28 to R-42 in custom homes. With respect to prescriptive insulation requirements, 17 of the 35 inspected homes with flat ceiling areas meet or exceed the 2006 and 2009 IECC prescriptive insulation requirement of R-38 insulation in flat ceilings; the weighted percentage is 50%. Figure 7-8 graphs the individual recorded flat ceiling insulation R-values for all 35 inspected homes with flat ceiling areas. For cathedral ceilings, both 2006 and 2009 IECC allow for R-30 insulation in up to 500 square feet of ceiling area without attic spaces, where the design of the roof/ceiling assembly does not allow sufficient space for R-38 insulation. Factoring this allowance into the percentage of homes meeting prescriptive insulation requirements, 11 of the 19 inspected homes with cathedral ceiling areas meet or exceed the 2006 and 2009 IECC prescriptive insulation level requirement for cathedral ceilings; the weighted percentage is 65%. Figure 7-9 graphs the individual recorded cathedral ceiling insulation R-values for all 19 inspected homes with cathedral ceilings.

Table 7-10: Flat Ceiling Insulation Statistics

Flat Ceiling Insulation R-value Statistics	All Homes (n=35)	Spec Homes (n=24)	Custom Homes (n=11)	Weighted* (Spec/ Custom)
Minimum R-value	19.0	19.0	28.0	19.0
Maximum R-value	57.0	57.0	42.0	57.0
Average R-value	**34.5**	**34.6**	**34.2**	**34.6**
Median R-value	37.5	37.7	33.6	37.5
Comparison to 2006 & 2009 IECC (R-38 in Flat Ceiling Areas)				
Less Than R-38	18 (51%)	12 (50%)	6 (55%)	50%
R-38	15 (43%)	11 (46%)	4 (36%)	45%
More Than R-38	2 (6%)	1 (4%)	1 (9%)	5%

*Only the average is weighted.

Figure 7-8: Recorded Flat Ceiling Insulation R-values

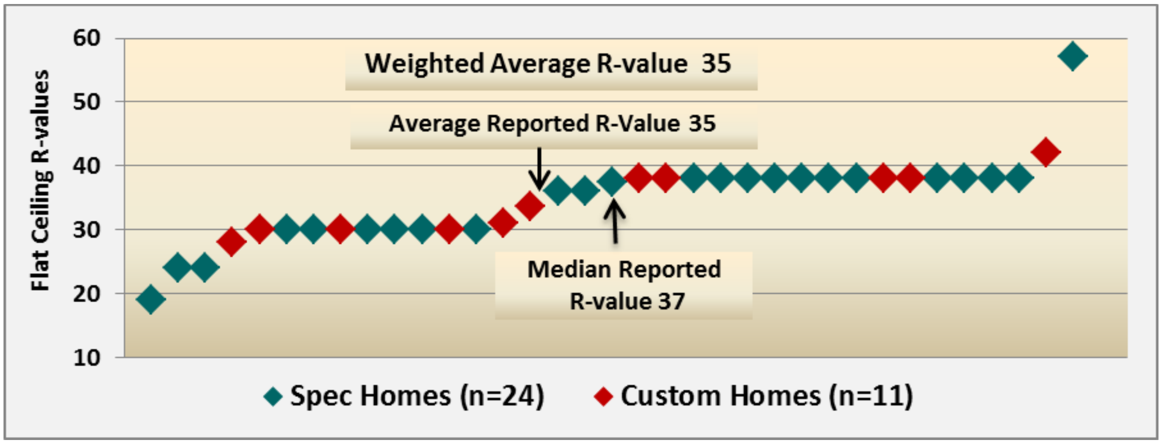


Table 7-11: Cathedral Ceiling Insulations Statistics

Cathedral Ceiling Insulation R-value Statistics	All Homes (n=19)	Spec Homes (n=9)	Custom Homes (n=10)	Weighted* (Spec/ Custom)
Minimum R-value	19.0	19.0	27.2	19.0
Maximum R-value	42.0	38.0	42.0	42.0
Average R-value	**33.0**	**32.8**	**33.2**	**32.8**
Median R-value	32.0	38.0	31.5	32.0
Comparison to 2006 & 2009 IECC (R-38 : Allows for R-30 for up to 500 Square Feet of Cathedral Ceiling Area)				
Less Than R-38 and/or More Than 500 sq. ft. Lower Than R-38	8 (42%)	3 (33%)	5 (50%)	35%
R-38 and/or Not More Than 500 sq. ft. Lower Than R-38 But at Least R-30	10 (53%)	6 (67%)	4 (40%)	64%
More Than R-38 and/or Not More Than 500 sq. ft. Lower Than R-38 But at Least R-30	1 (5%)	0 (0%)	1 (10%)	1%

*Only the average is weighted.

Figure 7-9: Recorded Cathedral Ceiling R-values

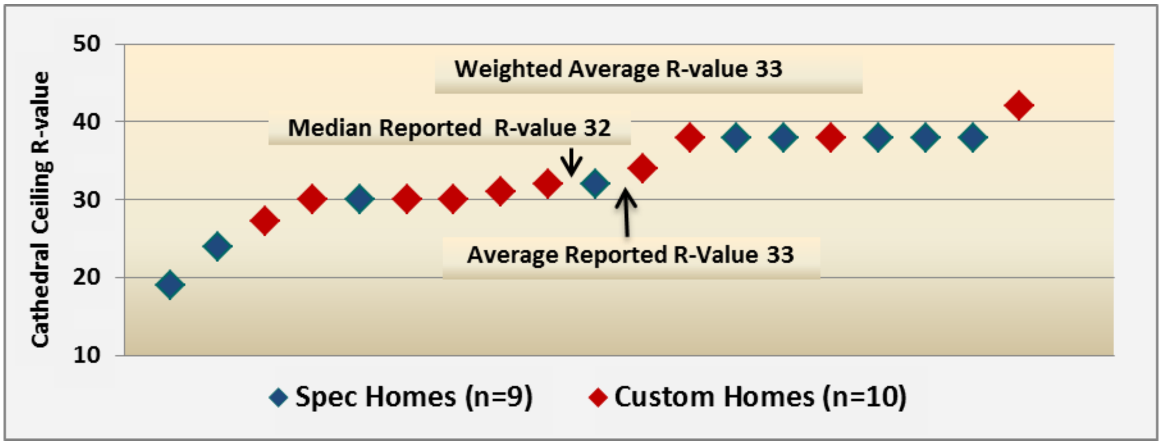


Table 7-12 shows overall how many inspected homes meet 2009 IECC prescriptive requirements for ceiling insulation. In this table, meeting requirements means both flat and cathedral ceiling areas in a home meet prescriptive requirements. The percentages of homes meeting requirements are lower than when looking at just flat or just cathedral ceilings. Weighted overall percentage of homes meeting all requirements is 50%.

Table 7-12: Overall Ceiling Insulation Statistics

Flat & Cathedral Ceiling Insulation Comparison to 2009 IECC Prescriptive Requirements	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=14)	Weighted (Spec/ Custom)
Comparison to 2006 & 2009 IECC (R-38 in Flat Ceilings and R-30 in not more than 500 Square Feet of Cathedral Ceiling Area)				
Flat < R-38 and/or Cathedral > 500 sq. ft. < R-38	20 (50%)	13 (50%)	7 (50%)	50%
R-38 Flat and Cathedral ≤ 500 sq. ft. < R-38	17 (43%)	12 (46%)	5 (36%)	45%
Flat > R-38 and ≤ 500 sq. ft. < R-38	3 (8%)	1 (4%)	2 (14%)	5%

7.3 Floor Insulation

Auditors recorded data on floor insulation between conditioned spaces and unconditioned basements, crawl spaces, garages and outside air. Table 7-13 through Table 7-16 show the characteristics of each floor type for all inspected homes, spec homes, custom homes and weighted data reflecting the mix of single-family spec and custom housing in the 2011 Program. Weighted average insulation levels are R-17.6 for conditioned/basement, R-25.6 for conditioned/garage, and R-23.8 for conditioned/ambient (outside air) floors.

Auditors were able to visually verify floor insulation, or the lack of insulation, for all floors over unconditioned basement space and crawlspaces. Insulation in conditioned/garage and conditioned/ambient floors are less likely to be verifiable; weighted percentages are 44% for conditioned/garage and 38% for conditioned/ambient floors. Auditors report seven homes with no insulation in conditioned/basement floor areas (six spec homes and one custom home); one custom home with no conditioned/garage floor insulation; and one spec home with no conditioned/ambient floor insulation.

Fiberglass batt insulation and 2 x 10 16 inch-on-center framing dominate. Floors in most inspected homes are insulated with only fiberglass batts; weighted percentages are 72% for conditioned/basement floors, 94% for conditioned/garage floors, 80% for conditioned/ambient floors and 50% for conditioned/crawlspace floors. Weighted percentages for 2 x 10 16 inch-on-center framing are 70% for conditioned/basement floors, 100% for conditioned/garage floors, 40% for conditioned/ambient floors and 53% for conditioned/crawlspace floors.

Auditors assigned a Grade I rating (the best) to floor insulation installations in only four homes. The Grade I ratings are for conditioned/garage and conditioned/crawlspace floors in one home, conditioned/ambient floors in two homes, and conditioned/garage floors in one home. All Grade I floor insulation installations are spray foam insulation.

Weighted Grade I insulation installation percentages are 0% for conditioned/basement, 4% for conditioned/garage, 5% for conditioned/ambient, and 3% for conditioned/crawlspace floors. Weighted Grade II insulation installation percentages are 45% for conditioned/basement, 34% for conditioned/garage, 30% for conditioned/ambient floors and 95% for conditioned/crawlspace floors. Weighted Grade III insulation installation percentages are 27% for conditioned/basement, 60% for conditioned/garage, 50% for conditioned/ambient floors and 3% for conditioned/crawlspace floors.

Table 7-13: Characteristics of Floors between Conditioned Space and Unconditioned Basement

Conditioned/Unconditioned Basement Floors	All Homes (n=27)	Spec Homes (n=20)	Custom Homes (n=7)	Weighted (Spec/ Custom)
Average R-value	18.3	17.2	21.7	17.6
Framing				
2 x 8 16" On Center	3 (11%)	2 (10%)	1 (14%)	10%
2 x 10 16" On Center	19 (70%)	14 (70%)	5 (71%)	70%
2 x 12 16" On Center	2 (7%)	1 (5%)	1 (14%)	6%
2 x 12 19" On Center	1 (4%)	1 (5%)	0 (0%)	5%
Truss	2 (7%)	2 (10%)	0 (0%)	9%
Insulation Verified, Installation Grade and Type				
Insulation Verified	27 (100%)	20 (100%)	7 (100%)	100%
Grade I Installation	0 (0%)	0 (0%)	0 (0%)	0%
Grade II Installation	12 (44%)	9 (45%)	3 (43%)	45%
Grade III Installation	8 (30%)	5 (25%)	3 (43%)	27%
n/a No Insulation	7 (26%)	6 (30%)	1 (14%)	28%
Only Fiberglass Batts	20 (74%)	14 (70%)	6 (86%)	72%
No Insulation	7 (26%)	6 (30%)	1 (14%)	28%

Table 7-14: Characteristics of Floors between Conditioned Space and Garage

Conditioned/ Garage R-value	All Homes (n=13)	Spec Homes (n=8)	Custom Homes (n=5)	Weighted (Spec/ Custom)
Average R-value	23.9	26.1	20.4	25.6
Framing				
2 x 10 16" On Center	13 (100%)	8 (100%)	5 (100%)	100%
Insulation Verified, Installation Grade and Type				
Insulation Verified	8 (62%)	**3 (38%)***	**5 (100%)***	44%
Grade I Installation	2 (15%)	0 (0%)	2 (40%)	4%
Grade II Installation	3 (23%)	**3 (38%)***	**0 (0%)***	34%
Grade III Installation	7 (54%)	5 (63%)	2 (40%)	60%
n/a No Insulation	1 (8%)	0 (0%)	1 (20%)	2%
Only Fiberglass Batts	10 (77%)	**8 (100%)***	**2 (40%)***	94%
Spray Foam	2 (15%)	0 (0%)	2 (40%)	4%
No Insulation	1 (8%)	0 (0%)	1 (20%)	2%

* Significantly different at the 90% confidence level.

Table 7-15: Characteristics of Floors between Conditioned Space and Outside Air

Conditioned/ Ambient Floors	All Homes (n=10)	Spec Homes (n=6)	Custom Homes (n=4)	Weighted (Spec/ Custom)
Average R-value	27.5	22.5	35.0	23.8
Framing				
2 x 8 16" On Center	2 (20%)	2 (33%)	0 (0%)	30%
2 x 10 16" On Center	6 (60%)	**2 (33%)***	**4 (100%)***	40%
2 x 12 16" On Center	1 (10%)	1 (17%)	0 (0%)	15%
Truss	1 (10%)	1 (17%)	0 (0%)	15%
Insulation Verified, Installation Grade and Type				
Insulation Verified	5 (50%)	2 (33%)	3 (75%)	38%
Grade I Installation	2 (20%)	**0 (0%)***	**2 (50%)***	5%
Grade II Installation	2 (20%)	2 (33%)	0 (0%)	30%
Grade III Installation	5 (50%)	3 (50%)	2 (50%)	50%
n/a No Insulation	1 (10%)	1 (17%)	0 (0%)	15%
Only Fiberglass Batts	7 (70%)	5 (83%)	2 (50%)	80%
Spray Foam	2 (20%)	**0 (0%)***	**2 (50%)***	5%
No Insulation	1 (10%)	1 (17%)	0 (0%)	15%

* Significantly different at the 90% confidence level.

Table 7-16: Characteristics of Floors between Conditioned Space and Crawlspace

Conditioned/Crawlspace R-value	All Homes (n=6)	Detached Homes (n=2)	Attached Homes (n=4)	Weighted (Spec/ Custom)
Average R-value	22.7	25.8	21.2	25.3
Framing				
2 x 8 16" On Center	1 (17%)	0 (0%)	1 (25%)	3%
2 x 10 16" On Center	4 (67%)	1 (50%)	3 (75%)	53%
2 x 10 24" On Center	1 (17%)	1 (50%)	0 (0%)	45%
Insulation Verified, Installation Grade and Type				
Insulation Verified	6 (100%)	2 (100%)	4 (100%)	100%
Grade I Installation	1 (17%)	0 (0%)	1 (25%)	3%
Grade II Installation	4 (67%)	**2 (100%)***	**2 (50%)***	95%
Grade III Installation	1 (17%)	0 (0%)	1 (25%)	3%
Only Fiberglass Batts	3 (50%)	1 (50%)	2 (50%)	50%
FG Batt and Foam Board	1 (17%)	1 (50%)	0 (0%)	45%
Spray Foam	2 (33%)	**0 (0%)***	**2 (50%)***	5%

* Significantly different at the 90% confidence level.

Table 7-17 summarizes weighted floor insulation R-value and comparisons with prescriptive insulation requirements. Table 7-18 through Table 7-21 provide statistics for all inspected homes, spec homes, custom homes and weighted data reflecting the mix of single-family spec and custom housing in the Program. Figure 7-10 graphs the individual recorded conditioned/basement insulation R-values for the 27 inspected homes with floors over unconditioned basement space.

Table 7-17 shows weighted average R-values range from R-17.6 for conditioned/basement floors to R-25.6 for conditioned/garage floors. The low average conditioned/basement floor R-value reflects the impact of seven homes with no insulation in conditioned/basement floors. The prescriptive floor insulation requirement under both 2006 and 2009 IECC is R-30 or a minimum of R-19 if the insulation fills the framing cavity. Weighted percentages of homes meeting prescriptive floor insulation requirements are 32% for conditioned/basement, 60% for conditioned/garage, 70% for conditioned/ambient, and 0% for conditioned/crawlspace floors.

Table 7-17: Weighted Floor Insulation Statistics

Floor Insulation R-value Statistics	Conditioned/ Basement Weighted* (Spec/Custom) (n=27)	Conditioned/ Garage Weighted* (Spec/Custom) (n=13)	Conditioned/ Ambient Weighted* (Spec/Custom) (n=10)	Conditioned/ Crawlspace Weighted* (Spec/Custom) (n=6)
Minimum R-value	0.0	0.0	0.0	15.0
Maximum R-value	38.0	30.0	42.0	27.5
Average R-value	**17.6**	**25.6**	**23.8**	**25.3**
Median R-value	19.0	30.0	30.0	22.8
Comparison to 2006 & 2009 IECC: R-30 or Filled Cavity (min R-19)				
Less Than R-30 or Cavity Filled < R-19	69%	40%	30%	100%
R-30 or Cavity Filled ≥ R-19	27%	60%	65%	0%
More Than R-30 or Cavity Filled > R-19	5%	0%	5%	0%

*Only the average is weighted.

Table 7-18: Floor Statistics—Conditioned/Basement

Insulation R-value Statistics Floors over Unconditioned Basements	All Homes (n=27)	Spec Homes (n=20)	Custom Homes (n=7)	Weighted* (Spec/ Custom)
Minimum R-value	0.0	0.0	0.0	0.0
Maximum R-value	38.0	38.0	30.0	38.0
Average R-value	**18.3**	**17.2**	**21.7**	**17.6**
Median R-value	19.0	19.0	24.0	19.0
Comparison to 2006 & 2009 IECC: R-30 or Filled Cavity (min R-19)				
Less Than R-30 or Cavity Filled < R-19	18 (67%)	14 (70%)	4 (57%)	69%
R-30 or Cavity Filled ≥ R-19	8 (30%)	5 (25%)	3 (43%)	27%
More Than R-30 or Cavity Filled > R-19	1 (4%)	1 (5%)	0 (0%)	5%

*Only the average is weighted.

Figure 7-10: Recorded Insulation R-values for Floors over Unconditioned Basements

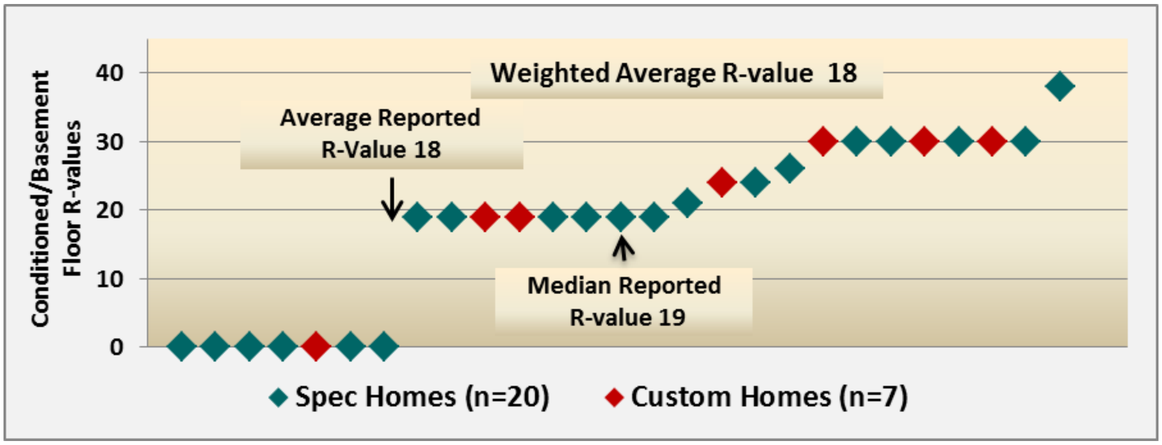


Table 7-19: Floor Statistics—Conditioned/Garage

Insulation R-value Statistics Conditioned/Garage Floors	All Homes (n=13)	Spec Homes (n=8)	Custom Homes (n=5)	Weighted* (Spec/ Custom)
Minimum R-value	0.0	19.0	0.0	0.0
Maximum R-value	30.0	30.0	30.0	30.0
Average R-value	**23.9**	**26.1**	**20.4**	**25.6**
Median R-value	30.0	30.0	21.0	30.0
Comparison to 2006 & 2009 IECC: R-30 or Filled Cavity (min R-19)				
Less Than R-30 or Cavity Filled < R-19	6 (46%)	3 (38%)	3 (60%)	40%
R-30 or Cavity Filled ≥ R-19	7 (54%)	5 (63%)	2 (40%)	60%
More Than R-30 or Cavity Filled > R-19	0 (0%)	0 (0%)	0 (0%)	0%

*Only the average is weighted.

Table 7-20: Floor Statistics—Conditioned/Ambient

Insulation R-value Statistics Conditioned/Ambient Floors	All Homes (n=10)	Spec Homes (n=6)	Custom Hom4s (n=4)	Weighted** (Spec/ Custom)
Minimum R-value	0.0	0.0	30.0	0.0
Maximum R-value	42.0	30.0	42.0	42.0
Average R-value	**27.5**	**22.5***	**35.0***	**23.8**
Median R-value	30.0	28.0	34.0	30.0
Comparison to 2006 & 2009 IECC: R-30 or Filled Cavity (min R-19)				
Less Than R-30 or Cavity Filled < R-19	2 (20%)	2 (33%)	0 (0%)	30%
R-30 or Cavity Filled R-19	6 (60%)	4 (67%)	2 (50%)	65%
More Than R-30 or Cavity Filled > R-19	2 (20%)	**0 (0%) ***	**2 (50%) ***	5%

* Significantly different at the 90% confidence level.
**Only the average is weighted.

Table 7-21: Floor Statistics—Conditioned/Crawlspace

Insulation R-value Statistics Conditioned/Crawlspace Floors	All Homes (n=6)	Detached Homes (n=2)	Attached Homes (n=4)	Weighted* (Spec/ Custom)
Minimum R-value	15.0	24.0	15.0	15.0
Maximum R-value	27.5	27.5	27.0	27.5
Average R-value	**22.7**	**25.8**	**21.2**	**25.3**
Median R-value	22.8	25.8	21.3	22.8
Comparison to 2006 & 2009 IECC: R-30 or Filled Cavity (min R-19)				
Less Than R-30 or Cavity Filled < R-19	6 (100%)	2 (100%)	4 (100%)	100%
R-30 or Cavity Filled R-19	0 (0%)	0 (0%)	0 (0%)	0%
More Than R-30 or Cavity Filled > R-19	0 (0%)	0 (0%)	0 (0%)	0%

*Only the average is weighted.

7.4 Windows

Auditors recorded the type(s) of windows in each home, but found it difficult to verify the U-value and solar heat gain coefficient (SHGC) for most windows.[24] Documented U-value and SHGC information was available for only one home where the original NFRC (National Fenestration Rating Council) sticker was visible. Auditors had access to the U-value and/or SHGC, or to information with which they could estimate the U-value and/or SHGC (such as the window manufacturer and series listed in a home's plans) for an additional four homes. Bearing in mind that the data were available for only one-eighth of the sample and therefore are not representative of all 40 homes, the U-values auditors gathered range from 0.29 to 0.35, with an average of 0.31. Similarly, the SHGCs auditors were able either to observe or reasonably estimate range from 0.27 to 0.47, with an average of 0.35. All five homes for which U-value and/or SHGC data were available have argon filled windows, and all five meet the 2009 IECC prescriptive code requirement of maximum U-0.35.[25]

When homeowners could not provide information on the type of glazing in their windows, auditors used either a lighter test or a Low-E coating detector to determine if the windows were Low-E.[26] Although auditors were not able to test for argon fill, in some cases they were able to estimate if a window had argon fill based on one or more of the following: the window manufacturer and series, verbal confirmation from the homeowner or builder, or inspection for the presence of plugs in the window frame visible between the panes of glass, which is typical of argon filled windows.

[24] The U-value is the direct inverse of the R-value; a higher U-value means a window is less efficient, allowing more heat to enter into or escape from the window. The Pacific Northwest National Lab explains, "In number values, R-value is the direct inverse of U-value (R-value=1/U-value). If a material has a U-value of .5, it has an R-value of 2. If it has a U-value of .25, it has an R-value of 4." Likewise, a lower SHGC is also desirable from an efficiency standpoint; the lower the SHGC, the more solar energy it blocks, leading to lower cooling costs.

[25] There are no 2009 IECC SHGC requirements for the climate zone in which Rhode Island is located.

[26] It is standard industry practice to use a lighter to determine whether or not a Low-E coating is present on windows; a lighter held up to the glass yields a different color flame if there is a Low-E glaze. If windows are not absolutely clean the Low-E coating detector can give different readings in different areas of a window.

REM/Rate and IECC default values for U-value and SHGC are shown in Table 7-22. REM/Rate defaults are more detailed—addressing more window categories—than IECC defaults. [27] However, both appear to be conservative. For example, the average U-value of the double pane, Low-E with argon, vinyl framed windows in the three inspected homes where the U-value could be documented is 0.31, which is more energy efficient than the REM/Rate default of U-0.33. Similarly, the average U-value of the double pane, low-e argon, wood framed windows in the two homes where the U-value could be documented is 0.31, which is more energy efficient than the REM/Rate default of U-0.36.

Table 7-22: REM/Rate and IECC Default Values for Missing Window Data

Operable Window Type	REM/Rate Defaults*		2009 IECC Defaults**	
	U-Value	SHGC	U-Value	SHGC
Double Pane Wood Frame	0.49	0.58	0.55	0.70
Double Pane Vinyl Frame	0.46	0.57		
Double Pane Fiberglass Frame	n/a	n/a		
Double Pane Low -E Vinyl Frame	0.36	0.45		
Double Pane Low-E Wood Frame	0.39	0.46		
Double Pane Low-E Argon Vinyl Frame	0.33	0.45		
Double Pane Low-E Argon Wood Frame	0.36	0.45		

*2005 ASHRAE Handbook—Fundamentals, section 31.8.
**2009 International Energy Conservation Code, p. 26.

In an effort to develop more realistic default window U-values, NMR evaluation team members talked to staff personnel at two large lumber yards that sell windows to builders of new homes and with five major window companies exhibiting at Build Boston: Andersen, Harvey, JELD-WEN, Marvin and Pella. Everyone said basically the same thing, that the standard today is an ENERGY STAR-qualified Low-E with argon window.

Representatives for Andersen, Pella, and Marvin windows say that, in most cases, Low-E windows without argon are special order. When asked what they estimated their share of the New England market for new construction windows was, the Andersen representative estimated 13% (7% nationally), the Marvin representative estimated 8%, and the Pella representative estimated 6%. All window representatives pointed out that there are many, many small manufacturers of windows selling to builders, and that some of these companies produce high quality windows and others produce low-end windows for builders unwilling to pay for ENERGY STAR-qualified windows.

One of the lumber yard representatives commented:

> *"Anecdotally, I see builders typically opting for the least expensive way to build which would mean Vinyl windows from Harvey Industries or Anderson 200 series.[28] As far as*

[27] Default values are from REM/Rate version 12.95. The REM/Rate default window values are based on the 2005 ASHRAE handbook.
[28] The Andersen representative said that the standard option for 200series windows is now Low-E with argon.

custom houses designed by Architects, I would say 99% are specified as an ENERGY STAR- rated window. There is really a huge difference between those custom homes and the spec houses being built out there."

Given that representatives of the major window manufacturers say their standard windows are ENERGY STAR-rated Low-E with argon, and current Version 5.0 ENERGY STAR window criteria for Rhode Island are U-0.32 or lower, depending on the SHGC (See Table 7-23), we propose an overall default window U-value of 0.34. A U-0.34 window does not meet current ENERGY STAR criteria for Rhode Island, and the U-value is higher than the standard U-value reported by the representatives of major window manufacturers; it may even be conservative. Without more information on what the large number of small window manufacturers are promoting and selling, it seems premature to assume a lower default U-value.

Table 7-23: Version 5.0 Northern Climate ENERGY STAR Window Criteria

Northern Climate ENERGY STAR Window Criteria as of January 4, 2010[29]			
U-Value	≤ 0.30	= 0.31	= 0.32
SHGC	Any	≥ 0.35	≥ 0.40

7.4.1 Window Types

Table 7-24 shows the percentages of homes with various windows types. As shown, the predominant weighted average window type is double pane Low-E vinyl framed (79%) followed by double pane Low-E argon vinyl framed (12%). As described earlier, the auditors tested for Low-E glazing, but not for argon fill. Therefore, the weighted average percentage of homes with argon filled windows may in fact be higher than 18%.

Table 7-24: Inspected Homes by Type of Window

Predominant Window Type	All Homes (n=40)	Custom Homes (n=14)	Spec Homes (n=26)	Weighted (Custom/ Spec)
Double Pane Low E Vinyl	30 (75%)	9 (64%)	21 (81%)	79%
Double Pane Low E Argon Vinyl	5 (13%)	2 (14%)	3 (12%)	12%
Double Pane Low E Argon Wood	4 (10%)	3 (21%)	1 (4%)	6%
Double Pane Low E Wood	1 (3%)	0 (0%)	1 (4%)	3%

[29] http://www.energystar.gov/ia/partners/prod_development/archives/downloads/windows_doors/WindowsDoorsSkylightsProgRequirements7Apr09.pdf

7.4.2 Glazing Percentage

Table 7-25 and Figure 7-11 provide statistics on glazing percentage. Glazing percentages are window areas as a percentage of conditioned/ambient wall area. As shown, glazing percentages range from 9% to 30%; the weighted average is 16%.

Table 7-25: Window Glazing Percentage Statistics

Percent Glazing Percent of Conditioned/Ambient Wall Area	All Homes (n=40)	Custom Homes (n=14)	Spec Homes (n=26)	Weighted (Custom/ Spec)*
Minimum	9%	10%	9%	9%
Maximum	30%	28%	30%	30%
Average	**17%**	**17%**	**16%**	**16%**
Median	16%	17%	15%	16%

*Only the average is weighted.

Figure 7-11: Glazing Percentage by Home

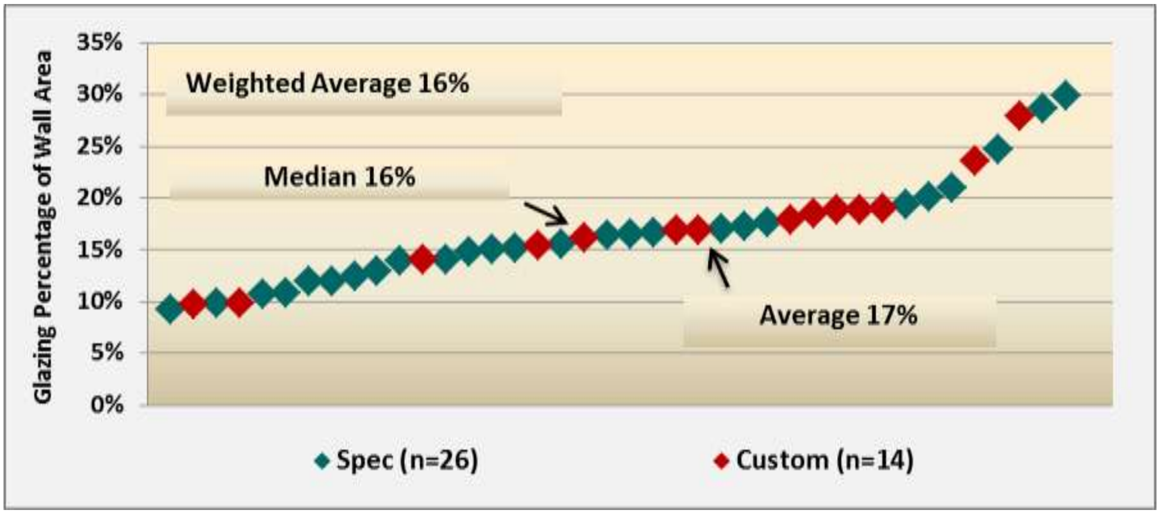


Table 7-26 shows the percent of south-oriented glazing. The percent of glazing oriented to the south ranges from 3% to 82%; the weighted average over all 40 homes is 39%.

Table 7-26: Percent of South Oriented Glazing

Percent of Exterior Wall South Glazing (S, SE, SW)	All Homes (n=40)	Custom Homes (n=14)	Spec Homes (n=26)	Weighted (Custom/ Spec)*
Minimum	3%	6%	3%	3%
Maximum	82%	67%	82%	82%
Average	**37%**	**34%**	**39%**	**39%**
Median	38%	29%	40%	38%

*Only the average is weighted.

7.4.3 Skylights

Only three out of forty inspected homes have skylights. Auditors were able to verify that two out of the three homes with skylights had skylights with a Low E glaze. The Low E glaze was verified with a Low E coating detector in one home while the skylights in the other home still had NFRC stickers on them. Note, for two out of the three homes auditors were unable to verify whether or not the skylights had argon fill in them. As is the case with windows, the NFRC sticker must be present on a skylight to determine whether or not it is filled with argon.

7.5 Doors

Auditors recorded information on 136 doors in the 40 sampled homes. Auditors only recorded information on doors that are part of the thermal boundary, including most exterior doors, and interior doors to unconditioned basements, garages, attics, and bulkheads. They did not record information on interior or exterior doors that are not part of the thermal boundary. Table 7-27 displays the weighted distribution of the types of doors. The weighted data show that steel is the most common type of door.

Table 7-27: Type of Door

Door Type	Doors Weighted (Custom/Spec) (n=136)
Steel	35%
Wood	34%
Fiberglass	31%

Table 7-28 shows the weighted percentage of doors with various characteristics. Most doors are insulated (66%), few have storm doors (8%), and over one-third of the doors (38%) contain glazing. The weighted average glazing area in doors with glazing is 7.7 square feet. Nearly all of the doors with glazing (97%) have either double pane Low-E (69%), double pane clear (18%), or double pane Low-E glass with argon (12%).

Table 7-28: Door Characteristics

Door Characteristics	Doors Weighted (Custom/Spec) (n=136)
Insulated	66%
Storm Door	8%
Glass in Door	38%
Doors with Glazing Weighted (Custom/Spec) (n=61)	
Avg. Sq. Ft. of Glass/Door	7.7
Double Pane Low-E	77%
Double Pane (clear)	16%
Double Pane Low-E Argon	4%
Single Pane	3%

7.6 Slab Insulation

Auditors were unable to observe underneath the slabs and, therefore, in most cases were able neither to confirm the existence nor record the R-values of slab floor insulation. Auditors were instructed to collect slab data for homes with conditioned basements; 4 of the 40 audited homes have conditioned basements. Table 7-29 displays the slab location for these four homes with conditioned basements. The majority of the homes have below grade slabs (three); one home has an on grade slab. The plans for one of the three homes with a below grade slab stated that it is insulated with R-10 expanded polystyrene. The homeowner of another of the three homes with a below grade slab stated that it is uninsulated. No information on slab insulation was available for the other two homes with conditioned basements.

Table 7-29: Slab Floor Location

Slab Floor Location	Count of Homes with Conditioned Basements (n=4)
Below Grade	3
On Grade	1

*Unweighted data.

7.7 Foundation Wall Insulation

By code, foundation walls in homes with conditioned basement space, where the conditioned space is bounded by a foundation wall, should be insulated. Code does not require foundation walls in homes with unconditioned basements or walls in conditioned basements where the conditioned space is not bounded by a foundation wall to be insulated. Only four of the 40 homes have conditioned basement space bounded by foundation walls.[30] The walls are typically finished (i.e., sheet rocked) in conditioned basements; therefore, the foundation wall insulation is not usually visible. This was the case in three of the four homes with conditioned basements. Auditors were able to visually confirm the foundation wall insulation in one of the four homes, and estimated the foundation insulation characteristics in the other three homes based on insulation they had visually confirmed in another area of the home. In all four homes, the foundation wall insulation is located on the interior foundation walls. As shown in Table 7-30, the most common type of foundation wall insulation is fiberglass batts; the weighted percentage is 95%. Please note this section only represents insulation that is in contact with the masonry foundation walls.[31]

Table 7-30: Type of Foundation Wall Insulation

Foundation Wall Insulation Type	All Homes (n=4)	Custom Homes (n=2)	Spec Homes (n=2)	All Homes Weighted (Custom/ Spec)
% Insulation Visible	1 (25%)	0 (0%)	1 (50%)	45%
Insulation Type				
Fiberglass Batts	3 (75%)	1 (50%)	2 (100%)	95%
Rigid Foam	1 (25%)	1 (50%)	0 (0%)	5%
Installation Grade				
Grade I Installation	2 (50%)	2 (100%)	0 (0%)	10%
Grade II Installation	2 (50%)	0 (0%)	2 (100%)	90%
Grade III Installation	0 (0%)	0 (0%)	0 (0%)	0%

[30] Three homes with slab on grade construction and foundation walls three feet or less in height have been excluded from the analysis in this section. In one of these three homes the foundation wall area is insulated with fiberglass batts; the foundation wall area is uninsulated in the other two homes.
[31] This section does not include insulation on top of masonry foundation walls. Walkout basements often have insulated wood-framed stud walls located on top of masonry foundation walls. These wood-framed walls are discussed in section 7.1 Wall Insulation.

The average insulation level for all four homes with conditioned basement space bounded by foundation walls is R-18.6. Again, please note that this section is only reporting on insulation that is in contact with the foundation walls, not insulation that is in wood-framed stud walls on top of masonry foundation walls. As shown in Table 7-31, the average insulation level is R-19 for spec homes and R-14.5 for custom homes. 2009 IECC prescriptive code requirement for foundation wall insulation is minimum R-10 for continuous insulation and R-13 for cavity insulation. All four homes meet or exceed the 2009 prescriptive insulation requirement.

Table 7-31: Foundation Wall Statistics

Foundation Wall Insulation Level	All Homes (n=4)	Custom Homes (n=2)	Spec Homes (n=2)	All Homes Weighted (Custom/ Spec)
Minimum R-value	13.0	13.0	19.0	13.0
Maximum R-value	19.0	16.0	19.0	19.0
Average R-value	**16.8**	**14.5**	**19.0**	**18.6**
Median R-value	17.5	14.5	19.0	17.5
Comparison to 2009 IECC (R-10/13)				
Less Than R-10/13	0 (0%)	0 (0%)	0 (0%)	0%
R-10/13	1 (25%)	1 (50%)	0 (0%)	5%
More Than R-10/13	3 (75%)	1 (50%)	2 (100%)	95%

7.8 Rim/Band Joist

Auditors recorded insulation information on all rim and band joists that were part of the thermal boundary and were not encompassed in other shell measures (i.e., frame floor). Insulating and air sealing rim/band joists is a mandatory requirement under the 2009 IECC. In general, rim joist insulation was visually verified while band joist insulation was not. In keeping with standard HERS rating practice, auditors assumed band joists were insulated similarly to conditioned/ambient walls so long as the walls above and below the joist were insulated when the home was built.[32] Rim joist insulation is often encompassed in the frame floor insulation. In many cases frame floor insulation extends all the way to the rim joist, in turn insulating the rim. In these cases rim joist insulation was not recorded as the rim joist is actually insulated by the frame floor insulation. The most pertinent example of this is in unconditioned basements where the frame floor insulation is separating the living space from the basement. In most of these cases the floor insulation is insulating the rim joist, removing the need to record rim joist insulation information.

[32] In a few instances the rim joist R-value was not the same as the exterior wall R-value. In these cases the band joist R-value was assumed to be the same as the rim joist, not the exterior walls.

Table 7-32 through Table 7-34 display a summary of the rim and band joist insulation recorded during the on-site visits.[33] The majority of rim and band joist insulation is located between conditioned spaces and ambient (outside) conditions. These joists have an average weighted R-value of R-14.6, all are spaced 16 inches apart (100%), and weighted results indicate just over one-half (56%) of these joists have a grade II installation.

Table 7-32: Joists between Conditioned Space and Outside Air

Conditioned/Ambient	All Homes (n=28)	Spec Homes (n=18)	Custom Homes (n=10)	All Homes Weighted (Spec/Custom)
Average R-value	17.3	13.6*	24.0*	14.6
Framing				
Joist 16" On Center	28 (100%)	18 (100%)	10 (100%)	100%
Insulation Installation Grade**				
Grade I Installation	5 (23%)	1 (8%)*	4 (44%)*	11%
Grade II Installation	9 (41%)	8 (62%)*	1 (11%)*	56%
Grade III Installation	8 (36%)	4 (31%)	4 (44%)	32%
Type of Insulation				
% Fiberglass Batt	17 (61%)	13 (72%)	4 (40%)	69%
No Insulation	5 (18%)	4 (22%)	1 (10%)	21%

*Spec homes are significantly different from custom homes at the 90% confidence level.

** Installation grade is only applied to sites where insulation was present.

Table 7-33: Joists between Unconditioned Basements and Outside Air

UC Basement/Ambient Joists	All Homes (n=5)	Spec Homes (n=4)	Custom Homes (n=1)	All Homes Weighted (Spec/Custom)
Average R-value	15.6	13.5	24	14.6
Framing				
Joist 16" On Center	4 (80%)	4 (100%)	0 (0%)	90%
Other Spacing	1 (20%)	0 (0%)	1 (100%)	10%
Insulation Installation Grade				
Grade I Installation	1 (25%)	0 (0%)	1 (100%)	10%
Grade II Installation	1 (25%)	1 (33%)	0 (0%)	30%
Grade III Installation	2 (50%)	2 (67%)	0 (0%)	60%
Type of Insulation				
% Fiberglass Batt	3 (60%)	3 (75%)	1 (100%)	78%
No Insulation	1 (20%)	1 (25%)	0 (0%)	23%

[33] One custom home has a rim joist located between an unvented crawl space and the outside. This rim joist has R-56 rigid foam insulation, the joists are spaced 16 inches apart, and the insulation installation was a grade I install.

Table 7-34: Joists between Conditioned Space and Garages

Conditioned/Garage	All Homes (n=6)	Spec Homes (n=6)	Custom Homes (n=0)	All Homes Weighted (Spec/Custom)
Average R-value	17.8	17.8	--	17.8
Framing				
Joist 16” On Center	5 (83%)	5 (83%)	0 (0%)	83%
Other Spacing	1 (17%)	1 (17%)	0 (0%)	17%
Insulation Installation Grade				
Grade I Installation	1 (17%)	1 (17%)	0 (0%)	17%
Grade II Installation	4 (67%)	4 (67%)	0 (0%)	67%
Grade III Installation	1 (17%)	1 (17%)	0 (0%)	17%
Type of Insulation				
% Fiberglass Batt	5 (83%)	5 (83%)	0 (0%)	83%
No Insulation	0 (0%)	0 (0%)	0 (0%)	0%

8 Mechanicals

This section addresses heating systems, cooling systems, water heating and mechanical ventilation.

8.1 Heating Systems

Most inspected homes have natural gas or propane heating systems, and most heating systems are installed in unconditioned space. Table 8-1, Table 8-2, and Table 8-3 show the primary heating fuels, types of heating systems and locations of heating systems. Data are shown for all inspected homes, spec homes, custom homes and weighted results reflecting the mix of single-family spec and custom housing in the 2011 Program. Table 8-1 shows most homes have either a natural gas or propane heating system; weighted results are 46% natural gas and 37% propane heating systems.

Table 8-1: Primary Heating Fuel

Primary Heating Fuel	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=14)	Weighted (Spec/ Custom)
Natural Gas	18 (45%)	12 (46%)	6 (43%)	46%
Propane	14 (35%)	10 (38%)	4 (29%)	37%
Oil	6 (15%)	4 (15%)	2 (14%)	15%
Electric	2 (5%)	0 (0%)	2 (14%)	1%

Table 8-2 shows spec homes are more likely than custom homes to have a furnace heating system and custom homes are more likely than spec homes to have a boiler heating system. Overall, the weighted furnace percentage is 51% and the weighted boiler percentage is 44%.

Table 8-2: Heating System Type

Heating System Type	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=14)	Weighted (Spec/ Custom)
Furnace	18 (45%)	14 (54%)	4 (29%)	51%
Boiler	19 (48%)	11 (42%)	8 (57%)	44%
Combination (water boiler)	1 (3%)	1 (4%)	0 (0%)	3%
GSHP	1 (3%)	0 (0%)	1 (7%)	1%
Electric resistance	1 (3%)	0 (0%)	1 (7%)	1%

Table 8-3 shows the most common location of heating systems, in both spec and custom homes, is an unconditioned basement; the weighted unconditioned basement percentage is 57%. The next most common locations are conditioned primary area (weighted average 18%) and attic (weighted average 12%).

Table 8-3: Heating System Location

Heating System Location	All Homes (n=44)	Spec Homes (n=28)	Custom Homes (n=16)	Weighted (Spec/ Custom)
Uncond. Basement	27 (61%)	9 (56%)	18 (64%)	57%
Cond. Primary Area	6 (14%)	3 (19%)	3 (11%)	18%
Attic	4 (9%)	2 (13%)	2 (7%)	12%
Cond. Basement	5 (11%)	1 (6%)	4 (14%)	7%
Vented Crawl Space	1 (2%)	1 (6%)	0 (0%)	6%
Garage	1 (2%)	0 (0%)	1 (4%)	0.4%

Most inspected homes have programmable thermostats; weighted percentage is 63%. Custom homes are more likely than spec homes to have a programmable thermostat; 79% of custom compared to 62% of spec homes. Not surprisingly, occupants of homes with programmable thermostats are much more likely to say they turn thermostat settings down at night and/or during the day if they are going to be out of the house than occupants of homes with non-programmable thermostats; weighted percentages are 91% compared to 40%.

There are several ways to group heating systems to compare efficiencies. Table 8-4 shows detailed AFUE statistics for all gas furnaces (natural gas and propane), natural gas furnaces, propane furnaces, gas (natural gas and propane) boilers, natural gas boilers, propane boilers, and oil boilers. Table 8-5 shows average AFUE, by type of heating system, for heating systems in all homes, spec homes, custom homes, and weighted average AFUEs reflecting the mix of single-family spec and custom housing in the 2011 Program. The weighted average AFUEs exceed ENERGY STAR minimum AFUEs for all but propane and oil boilers.[34]

Table 8-4: Furnace and Boiler Efficiency Statistics

Unweighted Heating System Efficiency Statistics	Gas Furnaces (Natural Gas & Propane) (n=22)	Natural Gas Furnaces (n=10)	Propane Furnaces (n=12)	Gas Boilers (Natural Gas & Propane) (n=14)	Natural Gas Boilers (n=9)	Propane Boilers (n=5)	Oil Boilers (n=6)
Minimum AFUE	80.0	92.1	80.0	83.1	83.2	83.1	81.0
Maximum AFUE	97.0	97.0	95.5	96.0	96.0	96.0	87.2
Average AFUE	**92.8**	**93.6**	**92.1**	**90.4**	**91.7**	**88.0**	**84.8**
Median AFUE	95.0	92.6	95.0	91.8	93.0	85.1	86.3

[34] ENERGY STAR minimum AFUEs: Natural gas and propane furnaces 90 AFUE, oil furnaces 85 AFUE, natural gas, propane and oil boilers 85 AFUE.

Table 8-5: Average AFUE by Type of Heating System and Housing

Average AFUE by System Type	Heating Systems in All Homes	Heating Systems in Spec Homes	Heating Systems in Custom Homes	Weighted (Spec/ Custom)
Gas Furnaces (Natural Gas & Propane)	92.8 (22 furnaces)	92.5 (16 furnaces)	93.6 (6 furnaces)	**92.6**
Natural Gas Furnaces	93.6 (10 furnaces)	**94.2 (7 furnaces)***	**92.1 (3 furnaces)***	**94.0**
Propane Furnaces	92.1 (12 furnaces)	**91.1 (9 furnaces)***	**95 (3 furnaces)***	**91.5**
Gas Boilers (Natural Gas & Propane)	90.4 (14 boilers)	**88.5 (8 boilers)***	**92.9 (6 boilers)***	**88.9**
Natural Gas Boilers	91.7 (9 boilers)	91.2 (5 boilers)	92.2 (4 boilers)	**91.3**
Propane Boilers	88 (5 boilers)	83.8 (3 boilers)	94.3 (2 boilers)	**84.9**
Oil Boilers	85.3 (6 boilers)	84.7 (4 boilers)	86.5 (2 boilers)	**84.9**

* Significantly different at the 90% confidence level.

UDRH inputs group heating systems by fuel and type of distribution system. Table 8-6 shows current UDRH heating system efficiency inputs and the average efficiencies for the different types of heating systems in all inspected homes, spec homes, custom homes, and weighted average efficiencies reflecting the mix of single-family spec and custom housing units in the 2011 Program. As shown, all weighted efficiencies are higher than current UDRH inputs except for oil air-distribution heating systems. The biggest increases in efficiency between current UDRH and 2011 baseline weighted efficiencies are for gas (natural gas and propane) hydronic distribution systems (81.7 to 88.7 AFUE) and gas (natural gas and propane) air distribution systems (89.2 to 92.2 AFUE). Not included in Table 8-6 are one ENERGY STAR-qualified ground source heat pump and one home that has electric resistance baseboard heat.

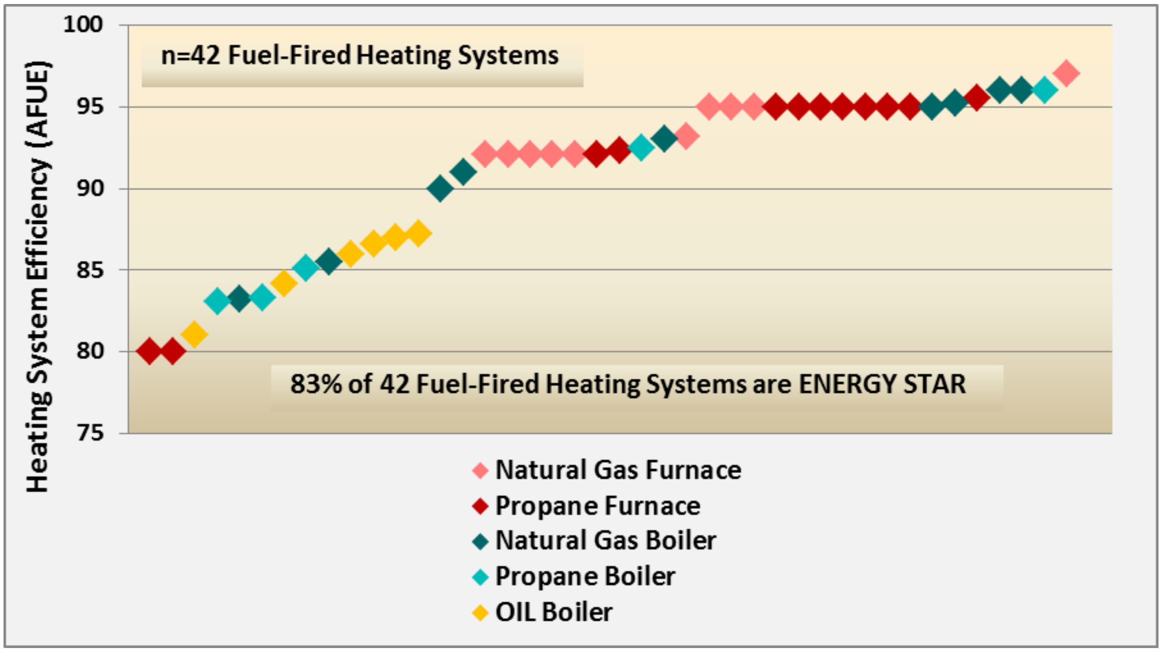
Table 8-6: Heating System Efficiencies by Fuel and Distribution System

Heating System Categories in UDRH	2005 UDRH Heating System AFUE	42 Heating Systems in 40 Homes		28 Heating Systems in Spec Homes		14 Heating Systems in Custom Homes		Weighted Average Efficiency (Spec/ Custom)
		Number of Heating Systems	Average AFUE	Number of Heating Systems	Average AFUE	Number of Heating Systems	Average AFUE	
Gas Air Distribution**	89.2	26	92.3	18	92.1	8	92.7	92.2
Gas Hydronic Distribution	81.7	10	90.5	6	**88.1***	4	**94.2***	88.7
All Gas Systems	88.5	36	91.8	24	91.1	12	93.2	91.3
Oil Air Distribution	83.9	2	84.0	1	81.0	1	87.0	81.6
Oil Hydronic Distribution	84.4	4	86.0	3	86.0	1	86.0	86.0
All Oil Systems	84.3	6	85.3	4	84.7	2	86.5	84.9

* Significantly different at the 90% confidence level.
**Gas heating systems include both natural gas and propane systems.

Figure 8-1 graphs the heating system AFUEs for the 42 natural gas, propane, and oil heating systems observed in inspected homes. The least efficient heating systems are two AFUE 80 propane furnaces and the most efficient heating systems are a mix of high-efficiency gas furnaces and boilers.

Figure 8-1: Heating System Efficiencies by Type of System



8.1.1 ECM Motor

An electronically commutated motor (ECM) is a brushless DC motor that offers efficiency gains relative to the industry standard permanent split capacitor (PSC) motors. ECMs offer two major advantages over PSC motors. First, studies have shown that ECMs use significantly less electricity than PSC motors while producing comparable air flow. Second, ECMs are variable speed motors with the flexibility to adjust air flow depending on the demand being called for by the furnace or central air conditioning system. As one author put it, "Multistage ECM furnaces offer a technological fix for the furnace-sizing problem; they operate mainly as smaller furnaces, but they offer that extra capacity to kick the temperature back up after a setback."[35]

Of the 22 furnaces inspected during the on-site visits, auditors found that 3 had ECMs while the remaining 19 had PSC motors.

[35] Scott Pigg, "The Electric Side of Gas Furnaces" *Home Energy Magazine*, November 1, 2003.

8.1.2 Heating System Capacity

Table 8-7 provides statistics on heating system Btuh per square foot. Output capacity Btuh per square foot ranges from 5 to 81 and the weighted average is 49 Btuh per square foot.

Table 8-7: Heating System Btuh per Square Foot Statistics

Heating System Output Capacity (Btuh) per Square Foot Conditioned Floor Area	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=14)	Weighted* (Spec/ Custom)
Minimum Btuh per Sq. Ft.	5	18	5	5
Maximum Btuh per Sq. Ft.	81	81	70	81
Average Btuh per Sq. Ft.	**48**	**50**	**44**	**49**
Median Btuh per Sq. Ft.	48	48	49	48

*Only the average is weighted.

8.1.3 Supplemental Heat Sources

More than half of inspected homes (58%) have at least one fireplace or stove.

Table 8-8 shows the number of fireplaces and stoves in homes. Weighted percentages are 45% no stoves or fireplaces, 48% one stove or fireplace and 7% two stoves or fireplaces.

Table 8-9 shows the percentages of natural gas, propane, and wood fireplaces and wood stoves in all homes, spec homes, custom homes, and the weighted average percentage reflecting the mix of single-family spec and custom housing in the 2011 Program. Weighted percentages are 43% natural gas, 30% wood, 20% propane, and 6% electric. Six homes (three spec and three custom) have wood fireplaces; the fireplaces doors are gasketed in three of these homes—one custom and two spec homes.

Table 8-8: Fireplaces and Stoves

Fireplaces & Stoves	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=14)	Weighted (Spec/ Custom)
None	**17 (43%)**	**12 (46%)**	**5 (36%)**	**45%**
One	**21 (53%)**	**12 (46%)**	**9 (64%)**	**48%**
Two	**2 (5%)**	**2 (8%)**	**0 (0%)**	**7%**

Table 8-9: Fireplace and Stove Fuel

Fireplace & Stove Fuel	All Homes (n=23)	Spec Homes (n=14)	Custom Homes (n=9)	Weighted (Spec/ Custom)
Natural Gas	10 (43%)	6 (43%)	4 (44%)	43%
Wood	8 (35%)	4 (29%)	4 (44%)	30%
Propane	4 (17%)	3 (21%)	1 (11%)	20%
Electric	1 (4%)	1 (7%)	0 (0%)	6%

8.1.4 Who Specified Heating System and Perceived Efficiency

All 40 homeowners completed the on-site survey, but not all owners responded to all questions. Therefore, the numbers of responses on which the presented results are based vary. The on-site homeowner survey asked owners who specified the heating system in their home. The choices were:

- I specified (Note that owners who are also the builder are treated as a separate category in this section.)
- Builder chose
- Selected from options offered by the builder
- Do not remember or do not know

If owners responded that they specified the heating system, they were asked, “Do you remember what you specified?” If they remembered, they were asked to check all options that applied; the options were:

- Heating fuel (electric, natural gas, propane, oil, etc.)
- Type of heating system (furnace, boiler, heat pump, ground source heat pump, etc.)
- Energy efficient heating system
- ENERGY STAR-labeled heating system

Owners were also asked to rate the energy efficiency of their heating system. The choices were:

- Not Energy Efficient
- Average Efficiency
- Very Energy Efficient
- ENERGY STAR Labeled
- Do Not Know

Who Specified Heating System

Thirty-five owners responded to the question asking who specified the heating system for their home. Figure 8-2 shows builders chose the heating system in just over half of these homes (18 homes or 51%). Eight owners plus all five owner/builders who completed the survey say they specified the heating system for their home and four owners say they selected from options offered by their builder.

Figure 8-2: Who Specified Heating System

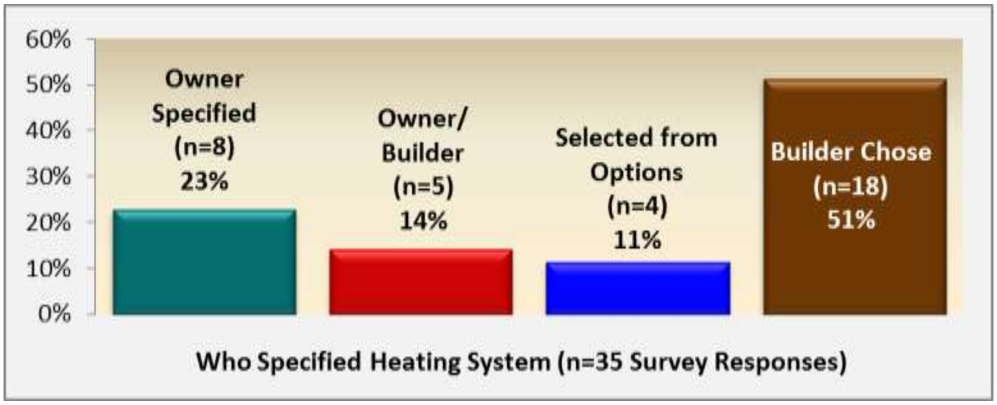


Table 8-10 shows what aspects of heating systems owners say they specified. (Note that some owners simply said they specified the heating system and did not identify what aspects of their heating system they specified.) As shown, owners who said they specified their heating system were most likely to say they specified the heating fuel (100%) and/or type of heating system (86%). In addition, almost two-thirds (64%) specified either an energy-efficient (43%) or an ENERGY STAR-labeled (21%) heating system.

Table 8-10: Heating System Aspects Owners Specified

Heating Systems: What Owners Specified (Multiple Responses)	Owners who Specified Aspects of Heating System (n=14)	
	# of Owners	% of Owners
Heating fuel	14	100%
Type of Heating System	12	86%
Energy Efficient Heating System	6	43%
ENERGY STAR-Labeled Heating System	3	21%

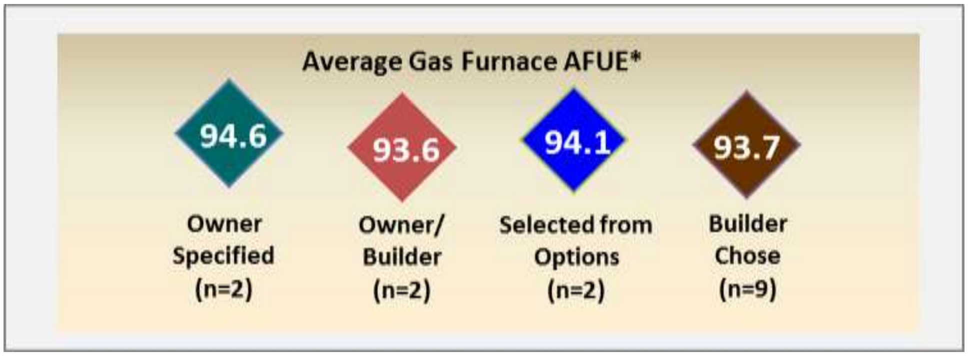
Figure 8-3 through Figure 8-5 show the average AFUEs for gas (natural gas and propane) furnaces, gas boilers, and oil boilers[36] by who specified the heating system.[37] In general, most

[36] No inspected home had an oil furnace.

inspected homes have high efficiency heating systems regardless of the type of heating system or who specified the heating system—the primary heating systems in 33 of the 39 inspected homes (85%) with heating systems eligible for ENERGY STAR certification are ENERGY STAR qualified.[38]

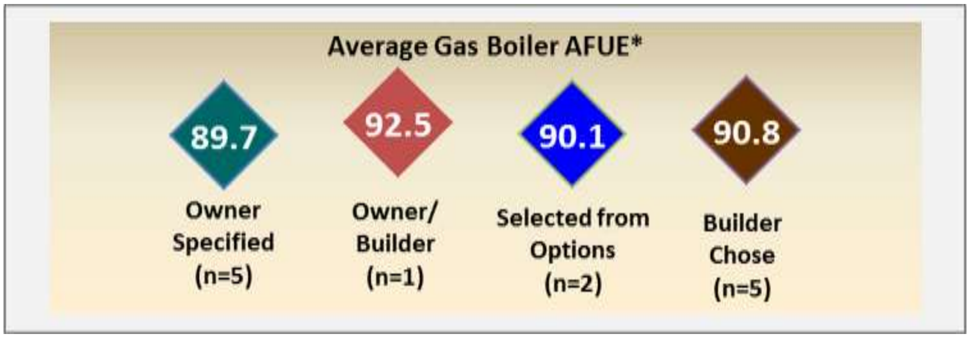
Understanding that most heating systems in inspected homes are very energy efficient, the average efficiencies of gas furnaces and oil boilers are highest in homes where non-builder owners specified the heating system. The average efficiency of gas boilers is highest in homes where owner/builders specified the heating system. The average efficiency of gas furnaces is lowest in homes where owner/builders specified the heating system; the average efficiency of gas boilers is lowest in homes where non-builder owners specified the heating system; the average efficiency of oil boilers is lowest in homes where builders chose the heating system. All average efficiencies exceed the minimum AFUE required for ENERGY STAR qualification with one exception—the average AFUE of oil boilers in homes where builders chose the heating system is 83.7, which is lower than the minimum ENERGY STAR criteria of AFUE 85.

Figure 8-3: Average Gas Furnace AFUE by Who Specified



*Includes both natural gas and propane furnaces.

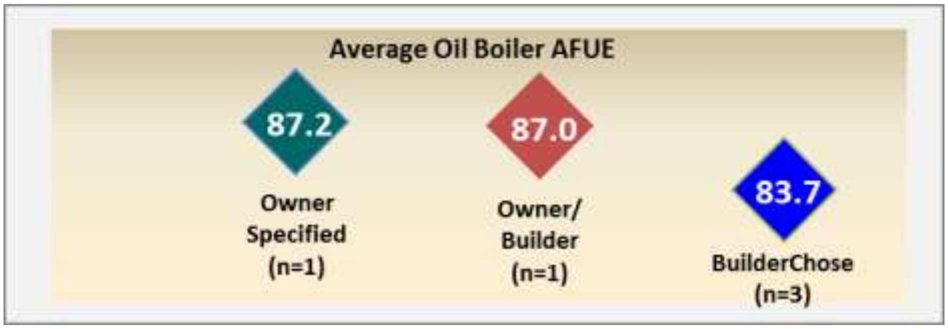
Figure 8-4: Average Gas Boiler AFUE by Who Specified



*Includes both natural gas and propane boilers.

[37] Not included in these figures are one home where the owner/builder specified electric resistance baseboard heat and one home where the builder chose an ENERGY STAR-qualified ground source heat pump.
[38] One home has electric resistance heat.

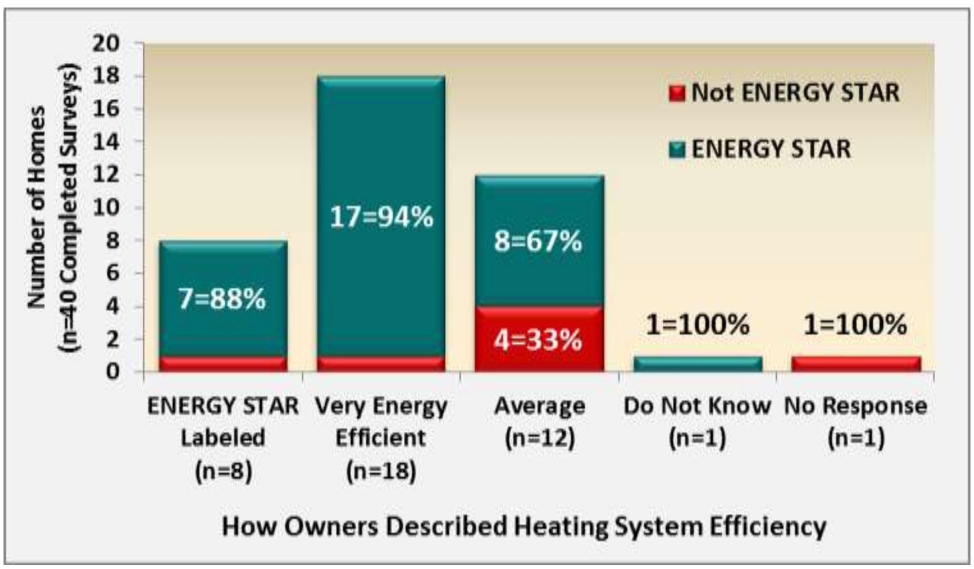
Figure 8-5: Average Oil Boiler AFUE by Who Specified



Perceived versus Actual Efficiency of Heating Systems

Figure 8-6 shows perceived versus actual ENERGY STAR heating systems. Seven of the eight survey respondents who think they have ENERGY STAR heating systems do. However, many homeowners who did not identify their heating systems as ENERGY STAR labeled also have ENERGY STAR heating systems. As shown, almost all (94%) of homeowners who say their heating systems are very energy efficient, but not ENERGY STAR, actually have ENERGY STAR heating systems, as do 67% of the homeowners who say the efficiency of their heating system is average, and the one homeowners who does not know how efficient his heating system is. Clearly, most homeowners do not know if their heating system is ENERGY STAR qualified.

Figure 8-6: Perceived versus Actual ENERGY STAR Heating Systems



8.2 Cooling Systems

When visiting homes, auditors gathered information on central air conditioning units. Most inspected homes (68%) have whole house central air conditioning. In addition, one home has a 1.5 ton SEER 19.0 ductless mini-split system used to cool part of the home. Of the 27 homes with central air conditioning installed, two-thirds (67% or 18 homes) have SEER 13 systems, which is the federal minimum efficiency level for residential central air conditioners manufactured after January 23, 2006. Only three homes have ENERGY STAR cooling systems; one spec and one custom home have ENERGY STAR-qualified central air conditioners and one custom home has an ENERGY STAR-qualified ground source heat pump.

Table 8-11 provides information on the number of central air conditioning units per home. Data are shown for all inspected homes, spec homes, custom homes and weighted results reflecting the mix of single-family spec and custom housing in the 2011 Program. Homes with central air conditioning have from one to four units. Weighted percentage are: 31% no central air conditioning, 42% one unit, 26% two units, and 1% four units.

Table 8-11: Number of Central Air Conditioning Units per Home

Number of Central Air Conditioning Units per Home	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=14)	Weighted (Spec/ Custom
One Unit	16 (40%)	11 (42%)	5 (36%)	42%
Two Units	10 (25%)	7 (27%)	3 (21%)	26%
Four Units	1 (3%)	0 (0%)	1 (7%)	1%
No Central Air Conditioning	13 (33%)	8 (31%)	5 (36%)	31%

Table 8-12 shows the location of central air conditioning units (air handler and coiling coil). As shown, most units are installed in unconditioned basements (weighted average 41%) or attics (weighted average 36%).

Table 8-12: Location of Central Air Conditioning Units

Central Air Conditioning Unit Locations	All CAC Units (n=40)	CAC Units in Spec Homes (n=25)	CAC Units in Custom Homes (n=15)	Weighted (Spec/ Custom
Unconditioned Basement	17 (43%)	10 (40%)	7 (47%)	41%
Attic	14 (35%)	9 (36%)	5 (33%)	36%
Cond. Basement	5 (13%)	4 (16%)	1 (7%)	15%
Cond. Primary Area	3 (8%)	2 (8%)	1 (7%)	8%
Vented Crawl Space	1 (3%)	(0%)	1 (7%)	1%

Total tons of air conditioning installed per home range from 2.0 to 9.1 tons. Table 8-13 shows the weighted average for all homes is 4.0 tons, which is much larger than the median of 3.0 tons—a few large systems drove up the average.

Table 8-13: Central Air Conditioning Tons per Home

Central Air Conditioning Tons per Home (Homes with CAC Data)	All Homes (n=27)	Spec Homes (n=18)	Custom Homes (n=9)	Weighted* (Spec/ Custom
Minimum	2.0	2.0	2.2	2.0
Maximum	9.1	7.5	9.1	9.1
Average	**4.1**	**3.9**	**4.5**	**4.0**
Median	3.0	3.0	4.0	3.0

*Only the average is weighted.

Table 8-14 shows square feet of conditioned floor area per ton of central air conditioning. As shown, values range from 348 to 1,788 and the weighted average is 625 square feet per ton.

Table 8-14: Square Feet of Conditioned Space per Ton of Central Air Conditioning

Square Feet per Ton CAC	All Homes (n=27)	Spec Homes (n=18)	Custom Homes (n=9)	Weighted* (Spec/ Custom
Minimum	348	348	456	348
Maximum	1,788	1,065	1,788	1,788
Average	**645**	**616**	**703**	**625**
Median	559	525	588	559

*Only the average is weighted

Auditors recorded model numbers for all central air conditioning units. All SEER and Energy Efficiency Ratio (EER) information available from equipment labels and nameplates was verified by looking up the model numbers in the Air Conditioning, Heating, and Refrigeration (AHRI) Directory of Certified Product Performance. Most (67%) of the 39 central air conditioning units with SEER information are SEER 13 units. Table 8-15 shows the SEERs of central air conditioning units range from 12.5 to 15.0. The weighted average SEER is 13.1; this is only slightly higher than the current UDRH input of SEER 13.0.

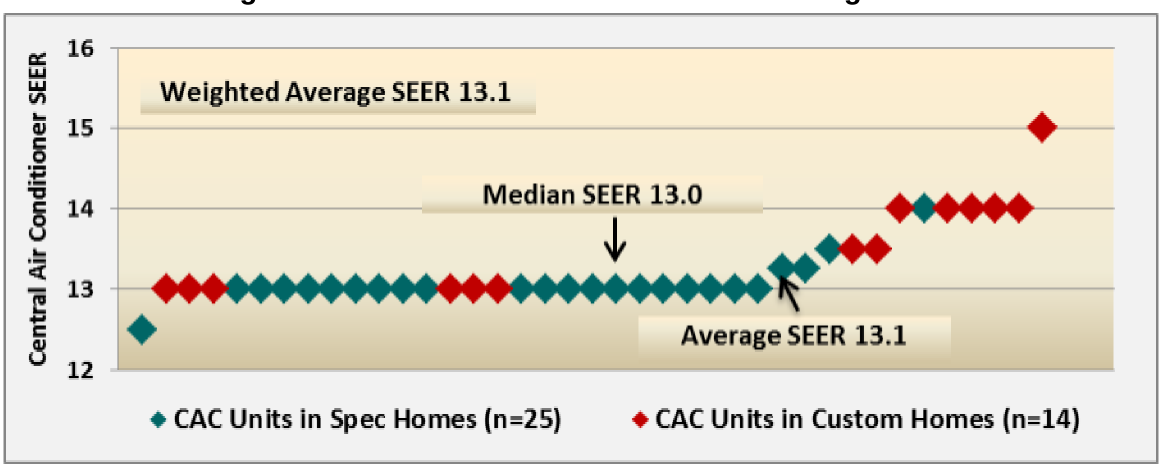
Table 8-15: Central Air Conditioning SEER

Central Air Conditioning SEER (CAC Units with SEER Data)	All Units (n=39)	CAC Units in Spec Homes (n=25)	CAC Units in Custom Homes (n=14)	Weighted** (Spec/ Custom
Minimum SEER	12.5	12.5	13.0	12.5
Maximum SEER	15.0	14.0	15.0	15.0
Average SEER	**13.2**	**13.1***	**13.6***	**13.1**
Median SEER	13.0	13.0	13.5	13.0

* Significantly different at the 90% confidence level.
**Only the average is weighted.

Figure 8-7 graphs the recorded SEER of individual central air conditioning units.

Figure 8-7: Recorded Central Air Conditioning SEER



8.2.1 Who Specified Cooling System and Perceived Efficiency

All 40 homeowners completed the on-site survey, but not all owners responded to all questions. Therefore, the numbers of responses on which the presented results are based vary. The on-site homeowner survey asked owners who specified the cooling system in their home. The choices were:

- I specified (Note that owners who are also the builder are treated as a separate category in this section.)
- Builder chose
- Selected from options offered by the builder
- Do not remember or do not know

If owners responded that they specified the cooling system, they were asked, "Do you remember what you specified?" If they remembered, they were asked to check all options that applied; the options were:

- Whether or not to install central air conditioning
- Type of system (standard central A/C system, air source heat pump, ductless mini-split system, combined heating and cooling system
- Energy efficient system
- ENERGY STAR-labeled system

Owners were also asked to rate the energy efficiency of their cooling system. The choices were:

- Not Energy Efficient
- Average Efficiency
- Very Energy Efficient
- ENERGY STAR Labeled
- Do Not Know

Who Specified Cooling System

Figure 8-8 shows builders chose the cooling system in 44% of the 25 homes with air conditioning whose owners responded to the question asking who specified the cooling system in their homes. Eight owners plus four owners who built their homes say they specified the cooling system for their home and two owners say they selected from options offered by their builder.

Figure 8-8: Who Specified Cooling System

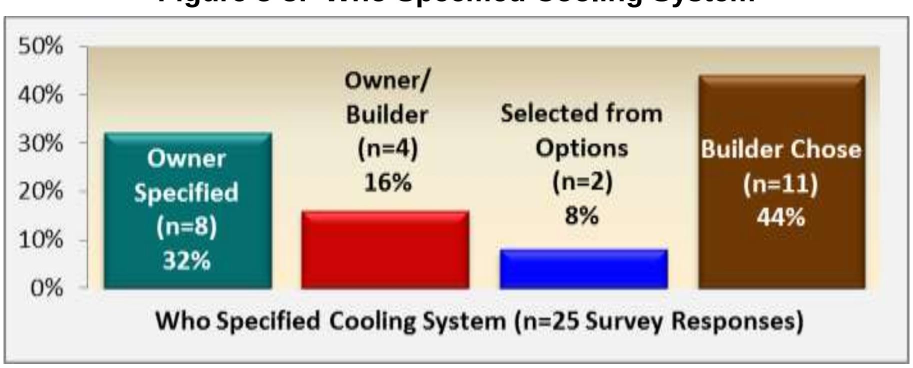


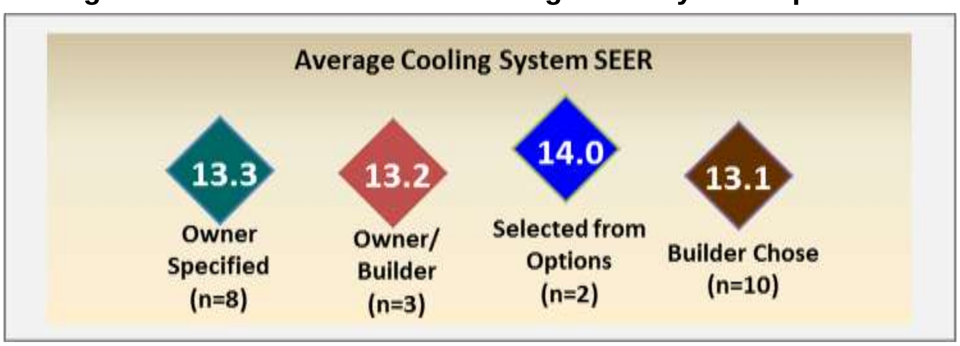
Table 8-16 shows what aspects of cooling systems owners, including owners who are also the builder, said they specified. (Note that some owners simply said they specified the cooling system and did not identify what aspects of their cooling system they specified.) As shown, owners who said they specified their cooling system were most likely to say they specified whether or not to install central air conditioning (80%), and/or the type of cooling system (70%); almost a third (30%) say they specified an ENERGY STAR cooling system and 10% an energy-efficient, but not ENERGY STAR, cooling system.

Table 8-16: Cooling System Aspects Owners Specified

Cooling Systems: What Owners Specified (Multiple Responses)	Owners who Specified Aspects of Cooling System (n=10)	
	# of Owners	% of Owners
Whether or not to Install Central Air Conditioning	8	80%
Type Of System	7	70%
Energy Efficient System	1	10%
ENERGY STAR-Labeled System	3	30%

Figure 8-9 shows the average SEER of cooling systems by who specified the cooling system. As shown, the average efficiency of cooling systems is highest (SEER 14.0) in the two homes where the owners selected the cooling system from options offered by their builder. The average efficiency of cooling systems in homes where non-builder owners, owner/builders or builders specified the cooling systems are similar, SEER 13.3, 13.2 and 13.1 respectively. Figure 8-9 does not include one custom home with an ENERGY STAR ground source heat pump that was specified by the builder and one custom home with a SEER 19 ductless mini split that cools only part of the home and was specified by the owner/builder.

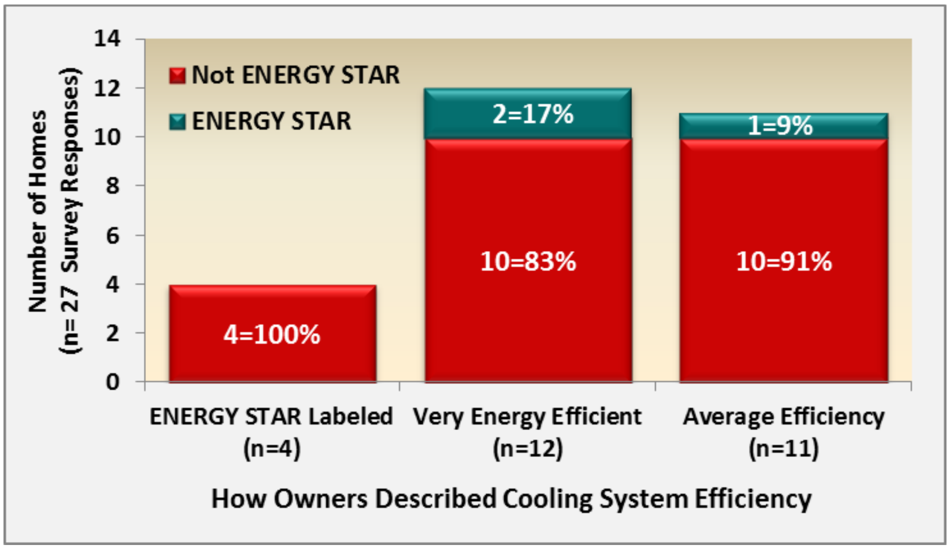
Figure 8-9: Central Air Conditioning SEER by Who Specified



Perceived versus Actual Efficiency of Cooling Systems

Figure 8-10 shows perceived versus actual ENERGY STAR cooling systems. As shown, none of the four owners who think they have ENERGY STAR cooling systems have ENERGY STAR systems. Two of the owners who think their cooling systems are very energy efficient, but not ENERGY STAR, and one of the owners who thinks his cooling system is average efficiency actually have ENERGY STAR-qualified cooling systems.

Figure 8-10: Perceived versus Actual ENERGY STAR Cooling Systems



8.3 HVAC Performance Testing

As part of this study, auditors performed in-field measurements to calculate the actual cooling capacities and efficiencies of a sample of residential central air conditioning (CAC) systems throughout the state. This report describes the in-field measurements, equipment, protocols and analytical procedures used to determine the actual operating characteristics of these systems. No central heat pumps were included in the sample. Although some of the RNC sample homes use window air conditioners, these units were not included in the CAC analysis.

8.3.1 Field Measured Data

The measurements required to properly assess the operating performance of the CACs include air side temperatures and flow rates and electric power draws of the condensing units and blower motors and controls. Although duct air leakage, which affects the system performance as a whole, was measured for the REM/Rate analyses, that was not a part of the CAC performance analysis.

Specific air side measurements included the following:

- Air flow rate in cubic feet per minute (CFM) through the evaporator coil,

- Supply air static pressure with filter in place,
- Supply air static pre with True Flow array in place,
- Supply air dry bulb temperature in degrees F,
- Supply air wet bulb temperature in degrees F,
- Return air dry bulb temperature in degrees F,
- Return air wet bulb temperature in degrees F.

Specific power side measurements included:

- Power input to the condensing unit (including the compressor) in Watts or kW,
- Power input to the blower motor and controls transformer in Watts.

8.3.2 Field Measurement Instrumentation

The instruments used in the field measurements had to yield enough precision to support the analysis without introducing unmanageable contradictions in the analysis at different stages. In keeping with this requirement, the evaluation team purchased relatively high precision thermometers and power meters and utilized a TrueFlow® Air Handler Meter designed specifically for the purpose of measuring air flow through a CAC system.

The instruments utilized during the in-field measurements included the following:

- TrueFlow® Air Handler Meter designed by The Energy Conservatory to measure CAC air flow to within 7%,
- Glass tube thermometers graduated to 0.2 degrees F,
- Hand held clamp-on true RMS power meters capable of +/- 1% accuracy at 40 Amps.

8.3.3 Field Measurement Protocols

The evaluation team utilized auditors that were already HERS certified or had completed the five day training required as part of HERS certification. These auditors were additionally trained both in the classroom and in the field at test sites and sample sites to conduct the CAC performance measurements. Emphasis was placed on the proper care, placement and usage of the instruments and on the importance of precision.

Specific field protocols included the following:

- Record the cooling temperature setting at the thermostat,
- Allow the house to warm up by disabling the cooling system during the blower door and duct leakage tests before starting the CAC performance measurements,
- Drill holes if necessary in the supply and return ducts to allow insertion of thermometers in appropriate locations to measure the supply and return air temperatures,
- Install the true flow array and set up its digital gauge to measure air flow in CFM,
- Locate the circuits in the breaker panel that feed the condensing unit and the blower motor and test the power meter Voltage reference contacts, Amp clamp and range setting,

- Set the control thermostat to its coldest setting and wait at least 5 minutes to allow the AC system to reach steady state operation,
- Have one auditor take the air side measurements while the other simultaneously takes the power readings, recording the start and end times to the nearest minute for each series of measurements,
- Record the simultaneous outside air temperature,
- Check the measurements for consistency against charts of reasonable ranges based on the equipment rated capacity and efficiency,
- Identify and correct any problems and repeat the series of readings if inconsistencies are observed,
- Repeat the series of measurements once or twice more, as required to obtain consistency between series,
- Observe and record the outdoor temperature again,
- Remove and pack all instruments, replace the filter, seal the holes in the ductwork and insulation using aluminum tape, and return the thermostat to its original setting.

8.3.4 Data Analysis

Field data were cleaned and analyzed utilizing a spreadsheet which calculates the field rated cooling capacity and efficiency of each system and converts said data to the standard conditions applied by the American Heating and Refrigeration Institute (AHRI) to rate the equipment. These results were then compared to the rated capacities and efficiencies observed on the equipment nameplates or taken from manufacturers' performance data for the model numbers on the nameplates.

Although the analytical formulae and processes were too complex and lengthy to describe textually in this report, a proprietary spreadsheet file with complete formulae will be made available for internal review.

The following steps outline the general analytical steps that were applied to all or most of the individual data sets:

- Clean the data by checking for expected reasonable ranges and referring back to the original audits when discrepancies were observed,
- Adjust the air flow measurements to normal by applying the supply air static pressure measurements both with true flow array in place and filter in place,
- Compare the dry bulb and wet bulb temperature measurements for consistency, correcting for obvious errors such as "slipped" decimal places, etc.,
- Compare temperature ranges against the adjusted air flow measurements to obtain a sanity check on the consistency of the data,
- Calculate the cooling capacity of the equipment at the field conditions from the air side measurements,

- Check the power measurements for consistency, converting any kW entries to Watts and correcting for obvious decimal place errors,
- Calculate the total power input in Watts by summing the condensing unit and blower motor/controls power,
- Calculate the ratio of the delivered cooling capacity in BTU per hour (Btuh) and Watts input to obtain EER in Btuh per Watt,
- Convert the actual field cooling capacity to rated capacity utilizing the field measured indoor and outdoor temperatures and the AHRI standard indoor and outdoor temperatures,
- Convert the actual field energy input ratio (EIR) to standard EIR utilizing the field measured indoor and outdoor temperatures and the AHRI standard indoor and outdoor temperatures,
- Convert standard EIR to EER and then to SEER to obtain the actual system efficiency at standard conditions.

8.3.5 Results

The overall results of this study are summarized in the following table (Table 8-17), which shows the average values of the 12 sites that yielded reasonable results:

Table 8-17: Rated vs. Measured Operating Performance of CACs

CAC Testing Results (n=12)	Rated	Operating	Difference	Relative Error
Capacity Btuh	**34,500***	**27,900***	-18.9%	10.7%
SEER	13.4	12.6	-5.5%	6.8%

*Significantly different at the 90% confidence level

The average rated capacity and efficiency was 34,500 Btuh (2.88 tons) and 13.4 SEER, as shown. The average operating capacity and efficiency was somewhat lower, at 27,990 Btuh (2.33 tons) and 12.6 SEER.

The differences between rated and operating capacity range from operating capacity 8.5% higher than rated capacity to 43.6% lower than rated capacity. At the same time, the differences between rated and operating efficiency range from operating efficiency 8.8% above rated efficiency to 34.2% below rated efficiency. These wide ranges may possibly indicate a wide range of actual operating conditions, but are probably also due to measurement errors.

A statistical Z test confirms that the average difference between rated and operating capacity is statistically significant at a 90% level of confidence, indicating that these values are valid indicators of the field performance condition overall. The same test applied to the difference in SEER, however, indicates that it is not valid at the 90% confidence level. Individual site performance comparisons are probably not reliable due to inherent field measurement errors.

Procedures required to obtain precise measurements of field operating conditions for any individual site would have required more precise instrumentation and more on-site time than the scope and budget for this project allowed. Even if these precision requirements had been met, the fact that these homes were occupied and the operating and weather conditions were not controlled within a tight range of temperatures would have made it virtually impossible to obtain highly precise test measurements at every site.

The evaluation team believes that the budget and scope to this CAC performance evaluation were appropriate for the desired metrics, and the field instruments and protocols were also appropriate.

8.4 Heating and Cooling Equipment Sizing –Manual J

One of the requirements of the 2011 Rhode Island Residential New Construction study was to contrast the central cooling and heating equipment capacities installed with the sizing requirements of the Eighth Edition of Manual J (MJ8). Similar to MJ8, REM/Rate provides both heating and cooling loads by component. The application of REM/Rate to size the cooling and heating systems was considered to be acceptable because REM/Rate design loads (cooling and heating loads under design conditions) agreed closely with MJ8 design loads for three randomly selected homes.

The REM/Rate input files were run to calculate the design cooling and/or heating loads for the 40 inspected homes, and the results are indicative of the MJ8 equipment sizing requirements. Twenty-seven of the inspected homes have central cooling systems installed. The REM/Rate results are probably more reliable and consistent with the objective of comparing actual installed equipment capacities to design equipment capacities because REM/Rate is a much more rigorous tool than MJ8, taking into account more detailed and specific site information to base the estimates on. At the same time the results are, on average, indicative of the MJ8 results as well.

8.4.1 Cooling System Sizing

Proper cooling equipment sizing is important for several reasons, the most important of which follow:

- Excessive oversizing causes the unit to operate for shorter periods of time, thus reducing the effective moisture removal capability. This may lead to discomfort, lower thermostat set points, or even allow mold or mildew to accumulate in humid climate conditions.
- Excessive oversizing may cause the system to cycle more often due to shorter run times. This may reduce the operating efficiency and decrease the working lifetime of the equipment.
- Excessively oversized equipment may emit more noise than necessary.
- Oversized systems lead to unnecessary costs.
- Oversized systems require larger equipment and ductwork, thereby increasing installation costs and causing installation problems when faced with limited spaces. Alternatively,

this could lead to undersized ductwork, thereby increasing the external static pressure and possibly resulting in insufficient evaporator air flow.

- Equipment undersizing may lead to unhappy owners if these systems fail to maintain reasonable comfort conditions during peak cooling periods. Installation of ceiling fans and/or some type of load reduction measures may often mitigate this problem, while also reducing the energy bills.

Table 8-18 shows the results for the 27 homes with central cooling. Following the conditioned floor area, the next two columns in Table 8-18 show the installed cooling capacities in BTUs per hour (Btuh) and tons. Next, the REM/Rate design loads are shown in both Btuh and tons, followed by proper cooling equipment size in tons.[39] The cooling system size ratio is the ratio of the actual cooling tons to the proper equipment size tons. As shown, the average size ratio is 1.54, indicating that the average installed cooling system rated capacity is 1.54 times the properly sized system capacity. The maximum ratio of all 27 sites is 2.40, and the minimum is 0.62. There is only one site with a ratio less than 1.00 and five sites at exactly 1.00, while the other 21 sites all have oversized cooling systems based on MJ8 sizing allowances. Therefore, 21 out of 27 sites, or 77.8%, have oversized cooling systems, with size ratios ranging from 1.20 to 2.40.

Table 8-18: Comparison of Actual Cooling Capacities and REM/Rate Design Loads

All Homes with Central Air Conditioning (n=27)	Cond. Floor Area Sq. Ft.	Actual Cooling Capacity Btuh	Actual Cooling Capacity Tons	REM/ Rate Cooling Load Btuh	REM/ Rate Cooling Load Tons	Proper Equipment Size Cooling Tons	Cooling System Size Ratio
Minimum	1,040	24,000	2.0	15,700	1.31	1.50	0.62
Maximum	5,244	108,800	9.1	58,000	4.83	5.00	2.40
Average	**2,464**	**49,667**	**4.1**	**29,041**	**2.42**	**2.69**	**1.54**
Median	2,361	36,000	3.0	27,600	2.30	2.50	1.50

Table 8-19 shows cooling system size ratio statistics for all centrally air conditioned (CAC) homes, spec homes and custom homes, while Figure 8-11 graphs the cooling system size ratios by home. As shown, the average cooling system size ratio is insignificantly higher for spec homes. The weighted average cooling system size ratio is 1.55.

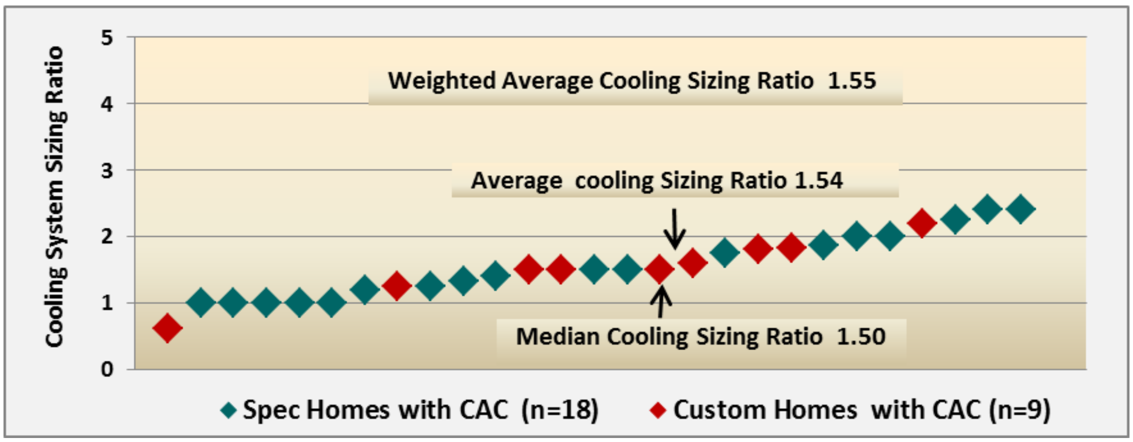
[39] The "Proper Equipment Size Cooling Tons" is the REM/Rate load in tons rounded up to the nearest half ton. This was done for each site, so the average of those (2.69) is not a rounded number and is slightly greater than the average REM/Rate load in tons.

Table 8-19: Cooling System Size Ratios

Cooling System Size Ratio	All Homes with CAC (n=27)	Spec Homes with CAC (n=18)	Custom Homes with CAC (n=9)	Weighted (Spec/ Custom)*
Minimum	0.62	1.00	0.62	0.96
Maximum	2.40	2.40	2.20	2.38
Average	**1.54**	**1.55**	**1.54**	**1.55**
Median	1.50	1.45	1.50	1.46

*Only the average is weighted.

Figure 8-11: Cooling System Size Ratios by Home



8.4.2 Heating System Sizing

Oversizing of heating equipment, regardless of type, may lead to excessive installation costs, excessive noise, and short cycling, the latter of which may reduce the annual efficiency and operating lifetime of the equipment. On the other hand, most homeowners like the "warm, fuzzy" feel of massive quantities of warm air emanating from their supply air registers or other heat distribution systems when they want to warm the house up quickly.

Table 8-20 shows the results for the 40 homes with heating systems. Following the conditioned floor area, the next column in Table 8-20 shows the installed heating capacities in BTUs per hour (Btuh). Next, the REM/Rate design loads are shown in Btuh, followed by the heating system size ratio. The heating system size ratio was calculated by taking the ratio of the installed heating capacity to the adjusted (rounded up to the nearest 10,000 Btuh) REM/Rate design load. The average heating equipment size ratio is 2.32. Three of the 40 sites (7.5%) have undersized heating system equipment, with a minimum size ratio of 0.28. All three of these homes have fireplaces and the home with the lowest size ratio is primarily a summer home. The remaining 37 homes (92.5%) have oversized heating systems, with size ratios ranging from 1.10 to 4.03.

Table 8-20: Comparison of Actual Heating Capacities and REM/Rate Design Loads

All Homes with Heating System (n=40)	Conditioned Floor Area Sq. Ft.	Actual Heating Capacity BTU/hr.	REM/Rate Heating Load BTU/hr.	Heating System Size Ratio
Minimum	935	19,500	14,400	0.28
Maximum	5,244	199,000	85,100	4.03
Average	**2,245**	**99,195**	**41,688**	**2.32**
Median	1,974	93,500	36,250	2.23

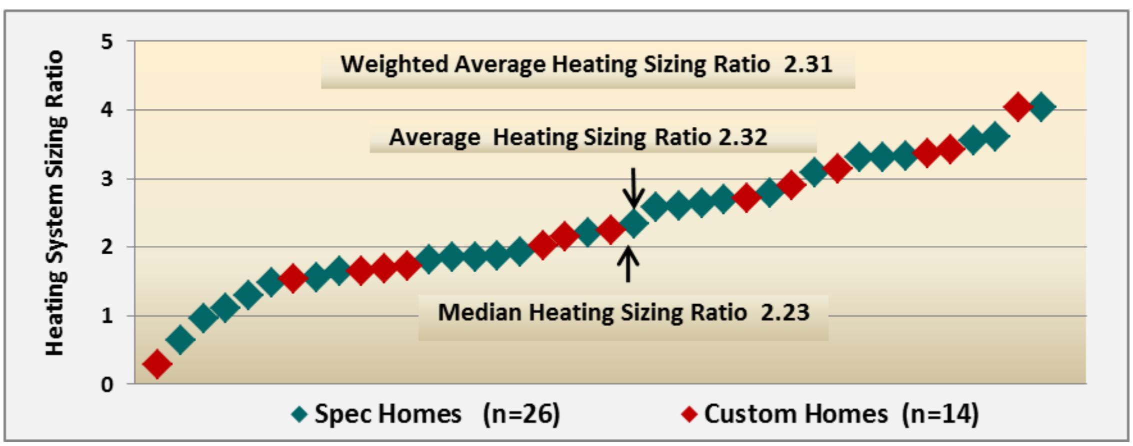
Table 8-21 shows heating system size ratio statistics for all homes, spec homes and custom homes, while Figure 8-12 graphs the heating system size ratios by home. As shown, the average heating system size ratio is slightly higher for custom homes; this difference is not statistically significant at the 90% confidence level. The weighted average heating system size ratio is 2.31.

Table 8-21: Heating System Size Ratios

Heating System Size Ratio	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=14)	Weighted* (Spec/ Custom)
Minimum	0.28	2.31	0.28	2.11
Maximum	4.03	4.03	4.03	4.03
Average	**2.32**	**2.31**	**2.35**	**2.31**
Median	2.23	2.27	2.20	2.26

*Only the average is weighted.

Figure 8-12: Heating System Size Ratios by Home



8.5 Water Heating

Auditors recorded information on 41 water heaters in the 40 inspected homes; one home has two instantaneous water heaters. Table 8-22 shows the numbers and percentages of the different types of water heaters observed. Data are shown for all inspected homes, spec homes, custom homes and weighted results reflecting the mix of single-family spec and custom housing in the 2011 Program. As shown, weighted percentages are 25% storage tanks integrated with boiler heating systems, 25% natural gas and propane conventional storage tank, 21% natural gas and propane instantaneous, 18% electric conventional storage tank, and 11% tankless coil water heating systems.

Table 8-22: Types of Water Heaters

Water Heater Types	All Water Heaters (n=41)	Water Heaters in Spec Homes (n=26)	Water Heaters in Custom Homes (n=15)	Weighted Spec/ Custom)
Integrated with Tank	12 (29%)	6 (23%)	6 (40%)	25%
Instantaneous	11 (27%)	5 (19%)	6 (40%)	21%
Conventional Storage (Natural Gas & Propane)	8 (20%)	**7 (27%)***	**1 (7%)***	25%
Conventional Storage (Electric)	6 (15%)	5 (19%)	1 (7%)	18%
Tankless Coil	4 (10%)	3 (12%)	1 (7%)	11%

*Significantly different at the 90% confidence level.

Table 8-23 shows most inspected homes have natural gas (43%) or propane (24%) water heating systems. Weighted percentages are 42% natural gas, 24% propane, 18% electric, and 15% oil.

Table 8-23: Water Heater Fuel

Water Heater Fuel By Home	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=14)	Weighted Spec/ Custom)
Natural Gas	17 (43%)	11 (42%)	6 (43%)	42%
Propane	11 (28%)	6 (23%)	5 (36%)	24%
Electric	6 (15%)	5 (19%)	1 (7%)	18%
Oil	6 (15%)	4 (15%)	2 (14%)	15%

Roughly two-thirds (65%) of inspected homes (26 out of 40 homes) have water heating systems with storage tanks. Table 8-24 shows over half of inspected homes have 40 to 50 gallon tanks. Weighted percentages are 13% less than 40 gallons, 64% 40 to 50 gallons, and 24% over 50 gallons.

Table 8-24: Water Heater Tank Gallons per Home

Water Heater Tank Gallons Per Home	All Homes with Storage Tanks (n=26)	Spec Homes with Storage Tanks (n=18)	Custom Homes with Storage Tanks (n=8)	Weighted Spec/ Custom)
Less than 40 Gallons	4 (15%)	2 (11%)	2 (25%)	13%
40 to 50 Gallons	15 (58%)	12 (67%)	3 (38%)	64%
Over 50 Gallons	7 (27%)	4 (22%)	3 (38%)	24%

Water heater Energy Factors vary widely depending on the type of water heating system. Table 8-25 on the next page shows that electric storage tank water heating systems in inspected homes have the highest average Energy Factor (0.91), followed by natural gas and propane instantaneous water heaters (average 0.87 Energy Factor), fossil-fuel fired integrated with tank water heaters (average 0.81[40] Energy Factor), conventional natural gas and propane storage tank water heaters (average 0.63[41] Energy Factor) and tankless coil water heaters (average 0.48 Energy Factor). The only statistically significant difference in average Energy Factors between inspected spec and custom homes is that the average Energy Factor of natural gas and propane instantaneous water heaters is significantly higher for inspected custom homes (average 0.89 Energy Factor) than spec homes (average 0.84 Energy Factor). All instantaneous water heaters in inspected homes are ENERGY STAR qualified.

Weighted average Energy Factors are 0.63 for conventional gas (natural gas and propane) storage tank water heaters, 0.91 for conventional electric storage tank water heaters, 0.79 for indirect water heating systems (storage tanks integrated with boiler heating systems), 0.85 for instantaneous gas (natural gas and propane) water heaters and 0.48 for tankless coil water heaters.

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[40] Energy Factors for integrated tank systems are calculated as 92% of the boiler heating system AFUE.

[41] Energy Factors of natural gas and propane conventional storage tank systems include an estimated Energy Factor for a 74 gallon conventional storage tank water heater that is not FVIR (Flammable Vapor Ignition Resistant) construction and does not have a reported Energy Factor. FVIR is a technology developed for gas-fired water heaters that resists ignition of flammable vapors that may occur outside and in close proximity to a water heater as a result of the mishandling of flammable products. (Source: http://www.bradfordwhite.com/fvirtech.asp) The Energy Factor for this water heater was estimated using the RESNET Energy Factor Calculator for Commercial DHW Tanks. (http://www.resnet.us/uploads/documents/standards/Commercial_Hot_Water_EF_Calculator_12-10.xls)

Table 8-25: Water Heater Energy Factor Statistics

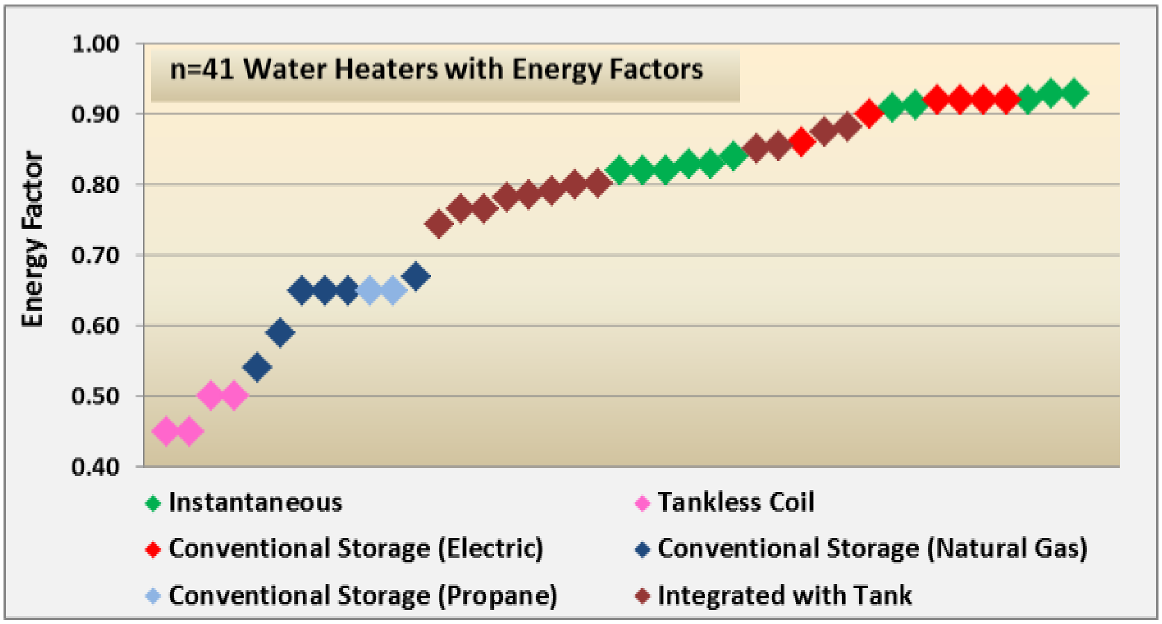
Conventional Storage Tank (Natural Gas & Propane)	All Water Heaters (n=8)	Water Heaters in Spec Homes (n=7)	Water Heaters in Custom Homes (n=1)	Weighted** Spec/ Custom)
Minimum Energy Factor	0.54	0.54	0.65	0.54
Maximum Energy Factor	0.67	0.67	0.65	0.67
Average Energy Factor	**0.63**	**0.63**	**0.65**	**0.63**
Median Energy Factor	0.65	0.65	0.65	0.65
Conventional Storage Tank (Electric)	**All Water Heaters (n=6)**	**Water Heaters in Spec Homes (n=5)**	**Water Heaters in Custom Homes (n=1)**	**Weighted** Spec/ Custom)**
Minimum Energy Factor	0.86	0.86	0.90	0.86
Maximum Energy Factor	0.92	0.92	0.90	0.92
Average Energy Factor	**0.91**	**0.91**	**0.90**	**0.91**
Median Energy Factor	0.92	0.92	0.90	0.92
Indirect: Integrated with Tank (Fossil-Fuel Fired)	**All Water Heaters (n=12)**	**Water Heaters in Spec Homes (n=6)**	**Water Heaters in Custom Homes (n=6)**	**Weighted** Spec/ Custom)**
Minimum Energy Factor	0.75	0.75	0.79	0.75
Maximum Energy Factor	0.88	0.88	0.88	0.88
Average Energy Factor	**0.81**	**0.79**	**0.83**	**0.79**
Median Energy Factor	0.80	0.77	0.83	0.80
Instantaneous (Natural Gas & Propane)	**All Water Heaters (n=11)**	**Water Heaters in Spec Homes (n=5)**	**Water Heaters in Custom Homes (n=6)**	**Weighted** Spec/ Custom)**
Minimum Energy Factor	0.82	0.82	0.82	0.82
Maximum Energy Factor	0.93	0.91	0.93	0.93
Average Energy Factor	**0.87**	**0.84***	**0.89***	**0.85**
Median Energy Factor	0.84	0.83	0.92	0.84
Tankless Coil	**All Water Heaters (n=4)**	**Water Heaters in Spec Homes (n=3)**	**Water Heaters in Custom Homes (n=1)**	**Weighted** Spec/ Custom)**
Minimum Energy Factor	0.45	0.45	0.45	0.45
Maximum Energy Factor	0.50	0.50	0.45	0.50
Average Energy Factor	**0.48**	**0.48**	**0.45**	**0.48**
Median Energy Factor	0.48	0.50	0.45	0.48

*Significantly different at the 90% confidence level
**Only the average is weighted.

Instantaneous and high efficiency conventional gas (natural gas and propane) water heaters are eligible for ENERGY STAR qualification. All instantaneous water heaters in inspected homes meet ENERGY STAR criteria. As of September 1 2010 the ENERGY STAR criteria for high efficiency gas conventional systems is an Energy Factor of 0.67; the prior criteria was an Energy Factor of 0.62. Only one conventional storage tank gas water heater meets current ENERGY STAR criteria. An additional three 0.65 Energy Factor conventional gas water heaters in homes completed in late 2010 or early 2011were likely purchased as ENERGY STAR-qualified water heaters from inventory stocked when the prior criteria were in effect.

Figure 8-13 graphs the water heating system Energy Factors for the 41 water heaters in inspected homes.

Figure 8-13: Water Heater Energy Factors by Type of System



8.5.1 Who Specified Water Heating System and Perceived Efficiency

All 40 homeowners completed the on-site survey, but not all owners responded to all questions. Therefore, the numbers of responses on which presented results are based vary. The on-site homeowner survey asked owners who specified the water heating system in their home. The choices were:

- I specified (Note that owners who are also the builder are treated as a separate category in this section.)
- Builder chose
- Selected from options offered by the builder
- Do not remember or do not know

If owners responded that they specified the water heater, they were asked, "Do you remember what you specified?" If they remembered, they were asked to check all options that applied; the options were:

- Fuel used to heat water
- Type of system (stand-alone tank, integrated tank with boiler, tankless, tankless combined with boiler heating system, point of use, etc.)
- Energy efficient system
- ENERGY STAR-labeled system

Owners were also asked to rate the energy efficiency of their water heater. The choices were:

- Not Energy Efficient
- Average Efficiency
- Very Energy Efficient
- ENERGY STAR Labeled
- Do Not Know

Who Specified Water Heater

Thirty-five owners responded to the question asking who specified the water heating system for their home. Figure 8-14 shows builders chose the water heaters in just over half of these homes (19 or 54%). Eight owners plus all five owner/builders who completed the survey say they specified the water heater for their home and three owners say they selected from options offered by their builder.

Figure 8-14: Who Specified Water Heater

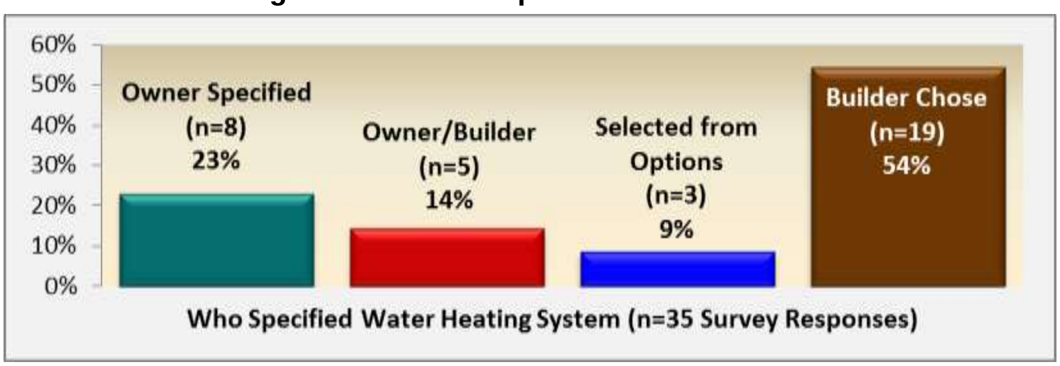


Table 8-26 shows what aspects of water heaters owners say they specified. (Note that some owners simply said they specified the water heating system and did not identify what aspects of their water heater they specified.) As shown, owners who said they specified their water heaters were most likely to say they specified the type of water heater system (92%) and/or the type of water heater fuel (85%). Over one-third (38%) of owners who say they specified their water heater specified an energy-efficient water heater, but not an ENERGY STAR-labeled water heater, and just under a third 31% say they specified an ENERGY STAR-labeled water heater.

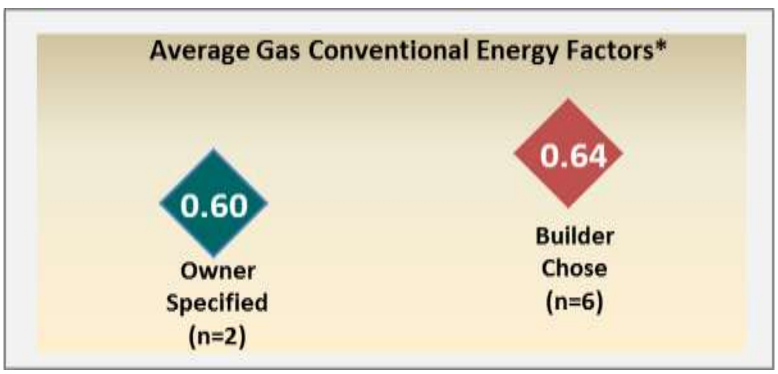
Table 8-26: Water Heater Aspects Owners Specified

Water Heating Systems: What Owners Specified (Multiple Responses)	Owners who Specified Aspects of Water Heating System (n=13)	
	# of Owners	% of Owners
Type of Water Heating System	12	92%
Water Heating Fuel	11	85%
Energy-Efficient Water Heater	5	38%
ENERGY STAR-labeled Water Heater	4	31%

Figure 8-15 through Figure 8-18 show the average Energy Factors for conventional gas (natural gas and propane) storage tank water heaters, conventional electric storage tank water heaters, indirect water heating systems (storage tanks integrated with boiler heating systems), and gas (natural gas and propane) instantaneous water heaters by who specified the water heater.

Figure 8-15 shows that conventional gas storage tank water heaters were specified by non-builder owners and builders. The average efficiency of conventional gas storage tank water heaters is higher in homes where the builder chose the water heater (Energy Factor 0.64) than in homes were the owner specified the water heater (Energy Factor 0.60).

Figure 8-15: Conventional Gas Storage Tank Water Heater Average Energy Factors by Who Specified



*Includes both natural gas and propane water heaters.

Figure 8-16 shows that conventional electric storage tank water heaters were specified by owners who also built their home and by builders. The average efficiency of conventional electric storage tank water heaters is the same for both groups of homes.

Figure 8-16: Conventional Electric Storage Tank Water Heater Average Energy Factors by Who Specified

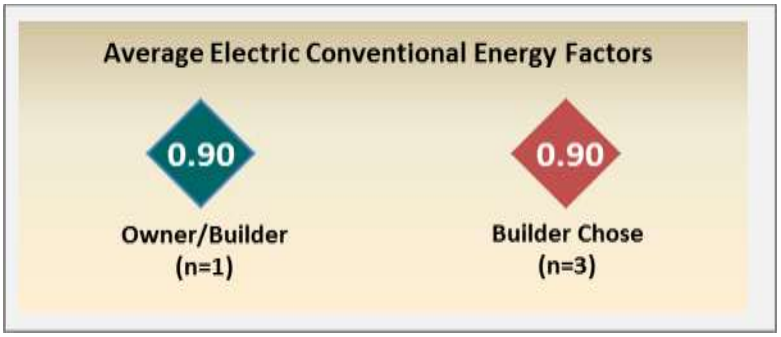


Figure 8-17 shows the average efficiency of indirect storage tank water heaters is highest in homes where the owner/builder specified the water heater (Energy Factor 083), then homes where non-builder owners specified the water heater (Energy Factor 0.81), then homes were builders chose the water heater (Energy Factor 0.80). The lowest average Energy factor is in the home where the owner selected the water heater from options offered by the builder (Energy Factor 0.79).

Figure 8-17: Indirect Storage Tank Water Heater Average Energy Factors by Who Specified

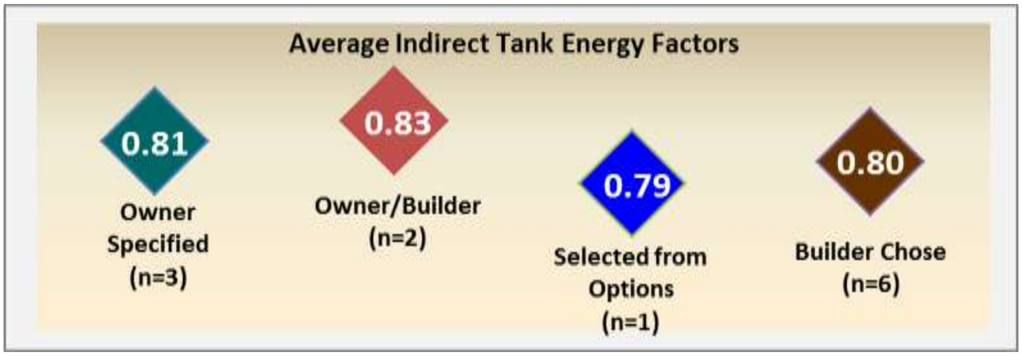
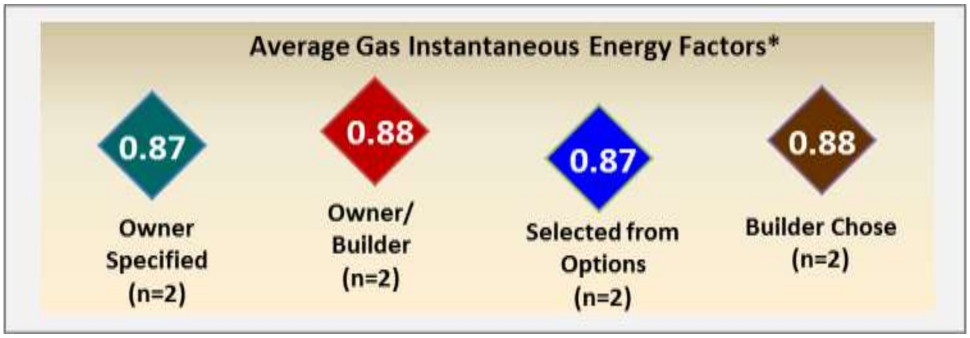


Figure 8-18 shows the average efficiency of instantaneous gas (natural gas and propane) water heaters is virtually the same regardless of who specified the water heater. The average Energy Factor in homes where the owner is the builder and in homes where the builder chose the water heater is 0.88. The average Energy Factor in homes where non-builder owners specified the water heater and in homes where owners selected from options offered by their builder is 0.87.

Figure 8-18: Instantaneous Gas Water Heater Average Energy Factors by Who Specified



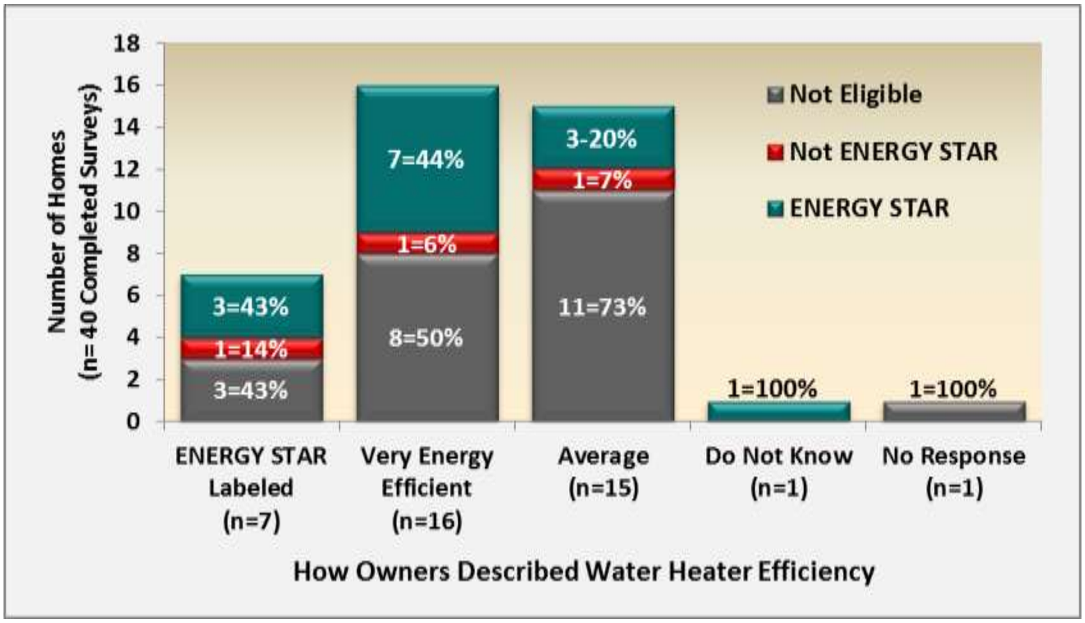
*Includes both natural gas and propane water heaters.

Perceived versus Actual Efficiency of Water Heaters

Only two types of residential water heaters encountered in the site visits are eligible for ENERGY STAR qualification—high-efficiency gas (natural gas and propane) storage and whole-home gas (natural gas and propane) tankless (instantaneous). To qualify for ENERGY STAR certification a gas instantaneous water heater must have an Energy Factor of 0.82 or higher. The criteria for ENERGY STAR-qualified gas storage water heaters changed as of September 1, 2010 from an Energy Factor of at least 0.62 to an Energy Factor of at least 0.67. Suppliers could sell any ENERGY STAR-labeled, in-stock water heaters with Energy Factors that met the old criteria as ENERGY STAR-compliant models until their stock was depleted. Because many of the inspected homes were completed prior to or within months of the change in criteria, it is likely that many of the gas storage water heaters with Energy Factors of at least 0.62, but below 0.67, were legitimately sold as ENERGY STAR compliant. Therefore, in this section, gas storage water heaters that meet the pre September 1, 2010 criteria for ENERGY STAR qualification are treated as being ENERGY STAR water heaters.

Figure 8-19 shows perceived versus actual ENERGY STAR water heaters. As shown, three of the seven owners who think they have ENERGY STAR water heaters do, and three owners have types of water heaters that are not eligible for ENERGY STAR qualification. Seven of the sixteen owners who think their water heaters are very energy efficient, but not ENERGY STAR, and three of the fifteen owners who think their water heaters are average actually have ENERGY STAR water heaters. The one owner who says he does not know how energy efficient his water heater is has an ENERGY STAR water heater.

Figure 8-19: Perceived versus Actual ENERGY STAR Water Heaters



8.6 Mechanical Ventilation

Auditors recorded information on mechanical ventilation during the on-site inspections. According to REM/Rate, mechanical ventilation is defined as "A fan designed to exchange the air in the house with outside air, sized to provide whole-house service per ASHRAE 62.2, and controlled automatically (i.e., not requiring human intervention to turn on and off)." Using this definition, only two of the audited homes have mechanical ventilation; one home has an Energy Recovery Ventilator (ERV) and one home has a Heat Recovery Ventilator (HRV). The difference between an HRV and an ERV is that an HRV recovers sensible (heat only) energy and the ERV recovers both sensible and latent (moisture) energy.[42]

ERVs and HRVs deliver balanced mechanical ventilation to the whole house. That is, they exhaust stale air from the home and deliver fresh outside air simultaneously. The ERV found onsite has net air flow ranging from 108 CFM to 178 CFM. The sensible recovery efficiency for this unit ranges from 65% to 71% and the total recovery efficiency is 69%. The HRV found

[42] Source: http://www.passivehouse.us/phc2011/2011%20Presentations%20PDF/ERV_HRV%20jm102011.pdf

onsite has net air flow ranging from 118 CFM to 160 CFM and has a sensible recover efficiency ranging from 55% to 61%.

All 40 inspected homes have bathroom exhaust fans. The number of exhaust fans per home is generally equal to the number of bathrooms per home. In total auditors counted 94 exhaust-only fans, ranging from one to four fans per home.

Auditors were unable to verify the exhaust rate for bathroom fans in any home. In general, bathroom fan exhaust rates range from 50 CFM to 150 CFM.

9 Ducts

9.1 Homes with Ducts

The majority of the inspected homes (27 out of 40) have ductwork. Only three homes have all ducts installed in conditioned space; an additional five homes have some ducts installed in conditioned space. Table 9-1 shows the various heating and cooling system combinations in the inspected homes. The majority of homes have a furnace with central air conditioning; the weighted percentage is 51%. The next most common heating and cooling system combination is a hot water boiler without central air conditioning (12 homes), followed by a hydro-air boiler[43] with central air conditioning (6 homes). All the homes in Table 9-1 with central air conditioning have ductwork.

Table 9-1: Mechanical Equipment

Heating/Cooling System Combination	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=14)	Weighted (Custom/ Spec)
Furnace with Central Air Conditioning	18 (45%)	14 (54%)	4 (29%)	51%
Boiler (hot water) without Central Air Conditioning	12 (30%)	8 (31%)	4 (29%)	31%
Boiler (hydro-air) with Central Air Conditioning	6 (15%)	3 (12%)	3 (21%)	13%
Boiler (hot water) with Central Air Conditioning	1 (3%)	0 (0%)	1 (7%)	1%
Ground Source Heat Pump with Central Air Conditioning	1 (3%)	0 (0%)	1 (7%)	1%
Electric resistance without Central Air Conditioning	1 (3%)	0 (0%)	1 (7%)	1%
Combination (water boiler) with Central Air Conditioning	1 (3%)	1 (4%)	0 (0%)	3%

[43] Hydro-air systems use a fuel burning boiler or hot water heater to produce hot water. The hot water is piped to an air handler, sometimes called a fan coil. Inside the air handler is a multi-row coil, through which the hot water is circulated. Air is then passed over the coil and ducted to the space. Source: http://www.warmair.net/html/hydro-air.htm

9.2 Duct Insulation Requirements

The 2009 IECC prescriptive code requirement for duct insulation is minimum R-8 for supply ducts located in attics, and minimum R-6 for all other ducts located in unconditioned space.[44] Table 9-2 shows that the weighted average R-value of duct insulation calculated over all types of ducts in all unconditioned locations is R-6.6. Of the 24 homes with ducts located in unconditioned space, eight meet or exceed the 2009 IECC prescriptive code requirement; the weighted percentage is 34%.

Table 9-2: Duct R-value Statistics

Duct Insulation Level All Ducts in Unconditioned Spaces	All Homes with Ducts Located in Unconditioned Space (n=24)	Spec Homes (n=17)	Custom Homes (n=7)	Weighted (Custom/ Spec)
Minimum R-value	0.0	0.0	0.0	0.0
Maximum R-value	10.0	10.0	9.6	10.0
Average R-value	**6.5**	**6.7**	**6.3**	**6.6**
Median R-value	6.4	6.4	6.9	6.4
Comparison to 2009 IECC (supply-attic R-8, all other R-6)				
Supply-Attic < R-8 and/or All Other < R-6	15 (63%)	10 (59%)	5 (71%)	60%
Supply-Attic R-8, All Other R-6	1 (4%)	1 (6%)	0 (0%)	5%
Supply-Attic ≥ R-8 and/or All Other ≥ R-6	7 (29%)	5 (29%)	2 (29%)	29%
Don’t Know*	1 (4%)	1 (6%)	0 (0%)	5%

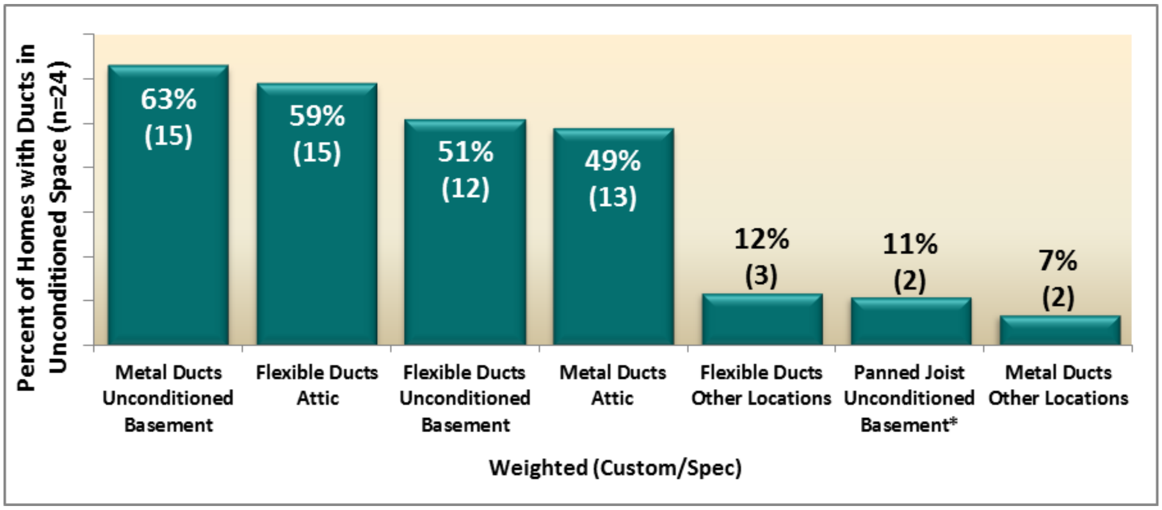
*Auditors were not able to record the R-value of insulation on attic supply ducts in one home; therefore, it is unclear whether this home meets the prescriptive code requirement of R-8 for supply ducts located in attics.

9.3 Duct Types and Insulation

For all supply and return ducts located in unconditioned space, auditors recorded the duct type (metal, flexible or duct board), location, insulation type and insulation R-value. Figure 9-1 shows the weighted percentage of all homes with ducts in unconditioned space that have metal, flexible or duct board ducts in unconditioned basements, attics or other locations.[45] Most homes have ducts in more than one location; therefore the percentages do not total 100%. Homes typically have a mix of metal and flexible ducts.

[44] Homes demonstrating compliance via the performance path must meet a mandatory minimum insulation requirement of R-6 for all ducts located in unconditioned space.
[45] Other locations include crawl spaces and garages.

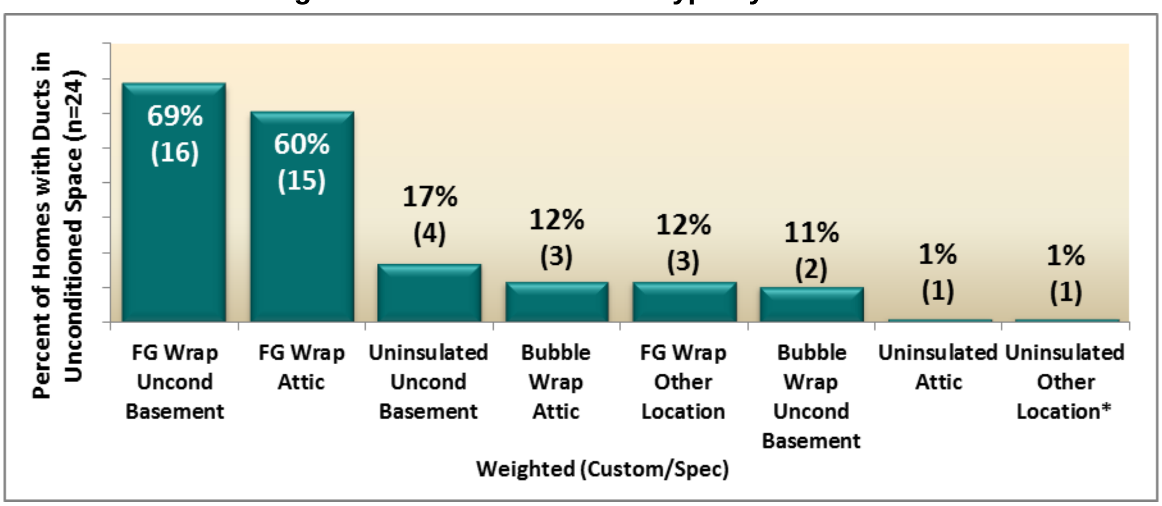
Figure 9-1: Duct Type by Location



*A panned joist is an example of using building framing as a portion of the return duct system. A panned joist is created by using sheet metal or duct board to enclose the space between the bottom edges of two vertical floor joists, and allowing return air to flow through this cavity back to the air handler.

Figure 9-2 shows the type of duct insulation by location for all homes with ductwork in unconditioned space. Fiberglass wrap (including pre-wrapped flex ducts) is the most common type of duct insulation. As shown, the weighted percentage of homes with ducts in unconditioned basements insulated with fiberglass wrap is 69%. The weighted percentage of homes with attic ducts insulted with fiberglass wrap is 60%. Six of the 24 homes have uninsulated ducts located in unconditioned space – three custom homes and three spec homes. The weighted results are 17% of homes with uninsulated ducts in an unconditioned basement, 1% with uninsulated ducts in the attic, and 1% with uninsulated ducts in another unconditioned location.

Figure 9-2: Duct Insulation Type by Location



*Refers to unconditioned spaces other than unconditioned basements and attics (i.e., crawl spaces and garages).

9.4 Duct Insulation R-values by Location

Table 9-3 shows the average R-value of duct insulation for supply and return ducts in unconditioned space by location. The average R-value for attic supply ducts in spec homes (7.7) is greater than in custom homes (6.9), and this difference is statistically significant at the 90% confidence level. The weighted average R-value for supply ducts in all unconditioned locations (6.9) is higher than for return ducts (6.1), although this difference is not statistically significant at the 90% confidence level. While the weighted average R-value for attic supply ducts (7.6) is greater than the weighted average R-values for supply and return ducts in all unconditioned locations, it is still less than the 2009 IECC prescriptive path minimum requirement of R-8 for supply ducts located in an attic.

Table 9-3: Average Supply and Return Duct Insulation R-value by Location

Duct Location	All Homes with Ducts Located in Unconditioned Space (n=24)			Spec Homes (n=17)			Custom Homes (n=7)			Weighted (Custom/ Spec)	
	n	Average Supply Duct R-value	Average Return Duct R-value	n	Average Supply Duct R-value	Average Return Duct R-value	n	Average Supply Duct R-value	Average Return Duct R-value	Average Supply Duct R-value	Average Return Duct R-value
Attic	16	7.4	7.1	11	7.7*	7.7	5	6.9*	5.8	7.6	7.5
Unconditioned Basement	16	6.5	5.2	12	6.4	5.1	4	7.3	5.6	6.4	5.2
Other**	3	7.2	2.1	2	6.7		1	8.0	2.1	6.8	2.1***
Average R-value Over All Ducts in Unconditioned Locations											
All Ducts in Unconditioned Space	24	7.0	5.9	17	6.9	6.3	7	7.2	5.1	6.9	6.1

* Significantly different at the 90% confidence level.

** Refers to unconditioned spaces other than unconditioned basements and attics (i.e., crawl spaces and garages).

***Unweighted data.

9.5 Conditioned Volume Basements

During the on-site visits NMR auditors treated two basements as conditioned volume and not conditioned floor area. Per RESNET standards[46] a home can only be considered conditioned floor area if it meets one of the following requirements:

- The space is finished and within the thermal boundary of the home.
- The space is unfinished and directly conditioned.

This definition does not account for spaces, such as unfinished insulated basements, that are part of thermal boundary but are not finished and are not directly conditioned. In this type of situation the space would be considered conditioned volume, but not conditioned floor area.

[46] http://www.resnet.us/standards/Floor_Area_Interpretation.pdf

One of the two homes home had a walk-out basement where the above grade walls on the walk-out were insulated with open cell spray foam and the frame floor separating the basement from the first floor was insulated with fiberglass batts. The other home had an unfinished basement with no foundation wall insulation and no frame floor insulation in the floor separating the basement from the first floor.

Zonal pressure tests were conducted at both of these homes to determine if the basement was more connected with the house than it was with the outside.[47] These basements were determined to be more connected to the house than to the outside and therefore were considered conditioned volume and the basement was included in all diagnostic tests.

Including these basements in the conditioned volume significantly affected the diagnostic results in these homes. The reason for this is that when a space is considered conditioned volume it must be included in the diagnostic tests per RESNET standards.[48] For duct leakage, this meant that the basement was pressurized during the leakage to outside tests and ultimately decreased the leakage to outside values for the distribution systems located in these basements. For air leakage, this meant the basement door was open during the blower door test and the volume of the basement was included in ACH50 (air changes per hour @ 50 Pa) calculations; increasing the volume in these calculations decreases the subsequent ACH50 value.

Including these basements in the conditioned volume is not consistent with how program raters would have assessed these homes. Therefore, these two homes are excluded from both duct leakage and air leakage values presented in the UDRH section of this report (see Preliminary User Defined Reference Home (UDRH) Inputs).

9.6 Duct Leakage

As discussed earlier, 27 of the 40 inspected homes have duct systems and in three of these homes all ducts are installed in conditioned space. Auditors conducted usable duct leakage tests at 22 of the 27 homes with ducts. The five homes where duct leakage testing was not done or the testing results are not usable are:

- Three homes where all ducts were in conditioned space and auditors assumed zero duct leakage to outside
- Two homes with duct systems in the basement and where the basement was considered conditioned volume but not conditioned floor area when testing duct leakage

In some cases, in homes with multiple duct systems, there was not enough time to test all systems or another reason why testing could not be conducted on a system. Other reasons why

[47] With the house depressurized to -50 Pascals (Pa), zonal pressure tests measuring the basement pressure with respect to (WRT) the house always had a reading of 25 Pa or less indicating the basement was more connected with the house than the outside.

[48] http://www.resnet.us/standards/DRAFT_Chapter_8_July_22.pdf

auditors were unable to test some duct systems include inaccessible vents in bathroom and kitchen in one home and an inaccessible major return in another.

Table 9-4 shows duct leakage statistics for the 22 tested homes with usable data. Data are shown for all inspected homes, spec homes, custom homes and weighted results reflecting the mix of single-family spec and custom housing in the 2011 Program. As shown, duct leakage to the outside ranged from 0.0 to 40.7 CFM25[49] per 100 sq. ft. of conditioned floor area. The weighted average is 20.0 CFM25 per 100 sq. ft. of conditioned floor area.

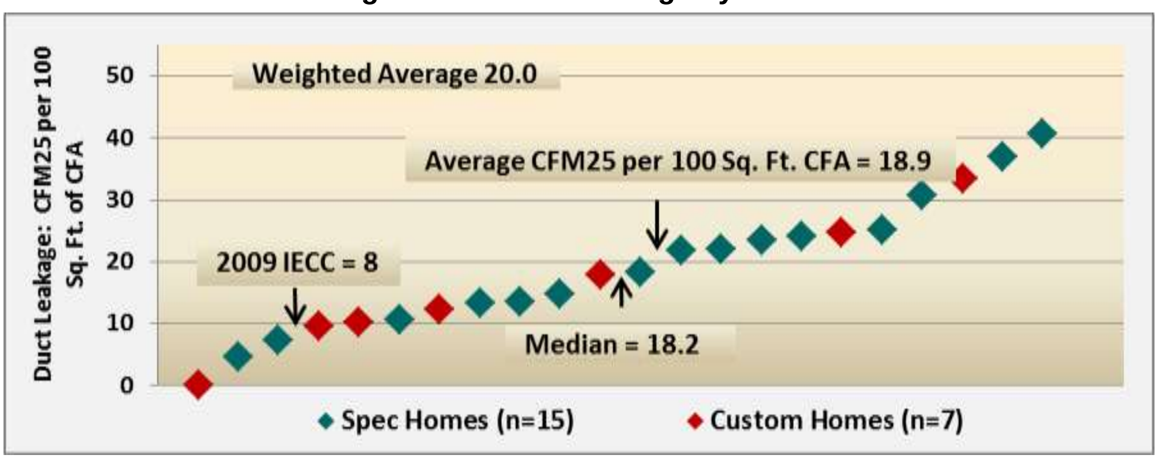
Table 9-4: Duct Leakage Statistics

Duct Leakage No Conditioned Volume Basements	All Homes (n=22)	Spec Homes (n=15)	Custom Homes (n=7)	Weighted Spec/ Custom)
Min	0.0	4.7	0.0	0.0
Max	40.7	40.7	33.4	40.7
Average	**18.9**	**20.5**	**15.4**	**20.0**
Median	18.2	21.9	12.2	18.2

*Only the average is weighted.

Figure 9-3 shows duct leakage by homes.

Figure 9-3: Duct Leakage by Home



[49] CFM25 is defined as the air flow (in cubic feet per minute) needed to create a 25 Pascal pressure change in the ductwork.

Mandatory 2009 IECC duct leakage requirements for ducts tested post construction are that homes meet one of the following:

- Leakage to outdoors less than or equal to 8 CFM25 per 100 ft^2 of conditioned floor area
- Total leakage less than or equal to 12 CFM25 per 100 ft^2 of conditioned floor area
- Duct tightness test is not required if the air handler and all ducts are located within conditioned space.

Table 9-5 shows duct leakage compliance statistics for 25 homes—22 homes where duct leakage testing was performed and 3 homes where the ducts were not tested, but all ducts were in conditioned space. As shown, 6 of the 25 homes complied with 2009 IECC mandatory duct leakage requirements: the weighted compliance rate is 20%.

Table 9-5: Compliance with 2009 IECC Mandatory Duct Leakage Requirements

Compliance with 2009 IECC Mandatory Duct Leakage Requirement	All Homes* (n=25)	Spec Homes (n=16)	Custom Homes (n=9)	Weighted Spec/ Custom)
Complies	6 (24%)	3 (19%)	3 (33%)	20%
Fails	19 (76%)	13 (81%)	6 (67%)	80%

*Includes three homes not tested—all ducts in conditioned space.

Putting duct leakage results into perspective, the average leakage to the outside of 18.9 CFM25 per 100 sq. ft. of conditioned floor area in homes where ducts were tested is:

- More than twice the 2009 IECC mandatory requirement of 8 or less CFM25 per 100 sq. ft. of conditioned floor area for ducts tested post construction
- More than four times the ENERGY STAR Version 3 performance path requirement that duct leakage to outdoors be 4 or less CFM25 per 100 sq. ft. of conditioned floor area
- More than four times the average duct leakage of 4.3 CFM25 per 100 sq. ft. of conditioned floor area in single-family homes completed through the 2011 Program

10 Air Infiltration

Auditors conducted blower door tests on all 40 of the inspected homes. As previously mentioned, results from two homes where the basement was considered conditioned volume have been excluded from the results presented below.

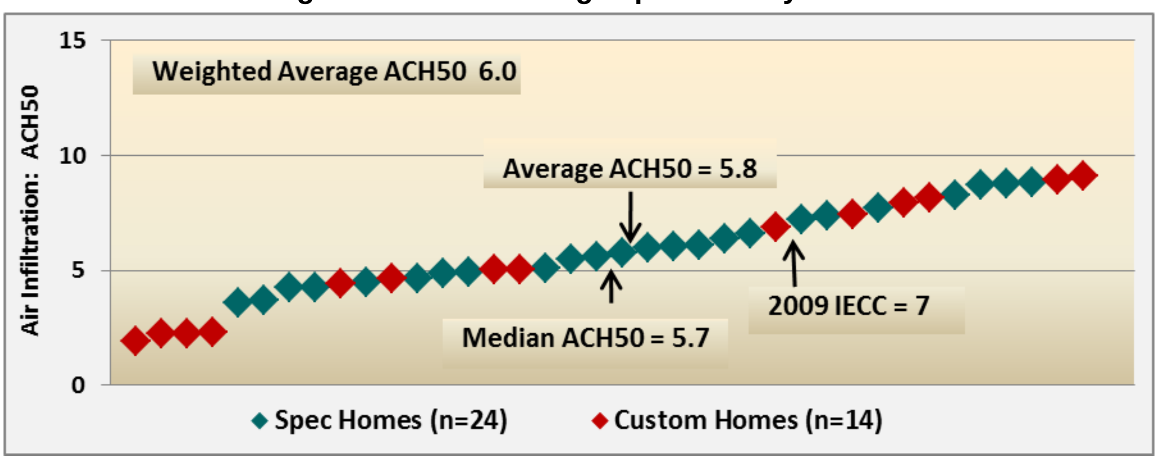
Blower door tests measure how airtight, or leaky, a home is and can determine the source of leaks. Homes that are too tight may need mechanical ventilation to bring air into the home. Very leaky homes will be expensive to heat and cool, and will likely feel drafty. Table 10-1 shows air changes per hour measured at 50 Pascals range from 1.93 to 9.07 in the 38 baseline homes with analyzed blower door testing results. Data are shown for all inspected homes, spec homes, custom homes and weighted results reflecting the mix of single-family spec and custom housing in the 2011 Program. The weighted average ACH50 is 5.96; this is lower than the current UDRH input of 6.72 ACH50. Figure 10-1 graphs ACH50 by home.

Table 10-1: Air Infiltration Statistics

ACH50 No Conditioned Volume Basements	All Homes (n=38)	Spec Homes (n=24)	Custom Homes (n=14)	Weighted* Spec/ Custom)
Minimum ACH50	1.93	3.57	1.93	1.93
Maximum ACH50	9.07	8.83	9.07	9.07
Average ACH50	**5.81**	**6.02**	**5.44**	**5.96**
Median ACH50	5.67	5.86	5.01	5.67

*Only the average is weighted.

Figure 10-1: Air Changes per Hour by Home



The overall average of 5.81 ACH50 and the weighted average of 5.96 ACH50 are lower than the 2005 Baseline Study average of 6.72 ACH50, which is the current Rhode Island UDRH input for air infiltration. 2009 IECC allows building tightness and insulation installation to be considered acceptable if tested air leakage is 7 ACH50 or lower; an impressive 76% or 29 of the 38 baseline homes with analyzed ACH50 data have 7 or lower ACH50. The ENERGY STAR Version 3 performance path requires air infiltration to be 4 ACH50 or lower; 16% or 6 of the 38 baseline homes have 4 or lower ACH50. Average air infiltration in 2011 Program homes was 3.9 ACH50; 16% or 6 of the 38 baseline homes have 3.9 or lower ACH50.

Table 10-2 shows total CFM50 for the 38 baseline homes ranges from 740 to 5,985; the raw data average is 1,768 and the weighted average is 1,684 CFM50.

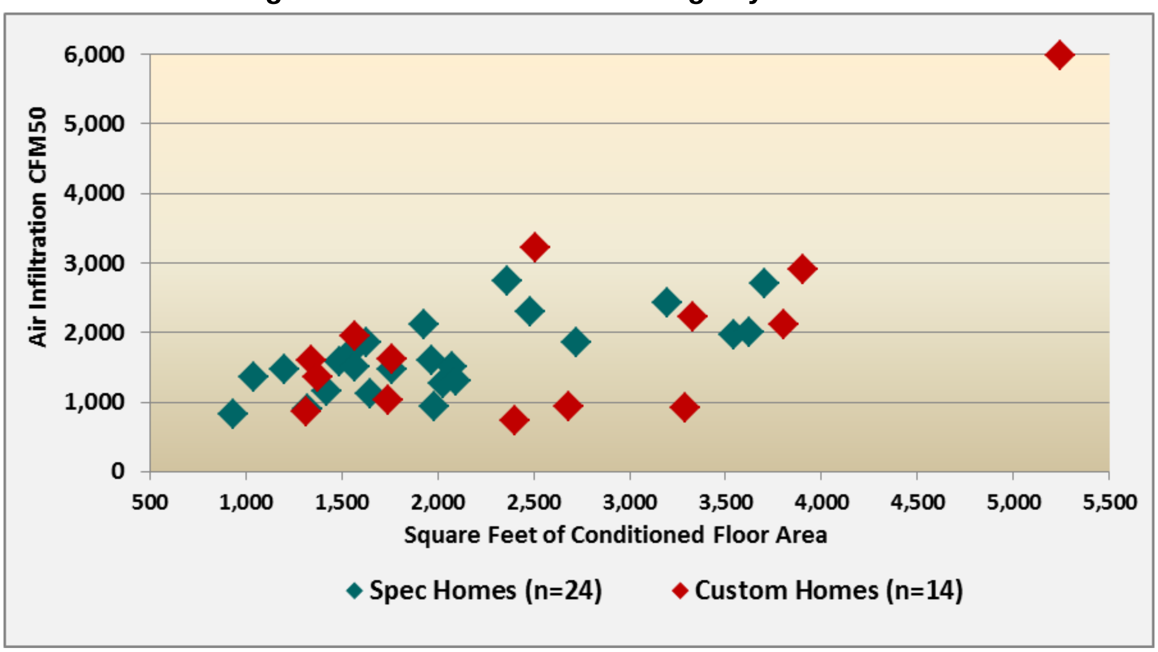
Table 10-2: Air Infiltration CFM50 Statistics

Air Infiltration CFM50	All Homes (n=38)	Spec Homes (n=24)	Custom Homes (n=14)	Weighted* (Spec/ Custom)
Min	740	818	740	740
Max	5,985	2,739	5,985	5,985
Average	**1,768**	**1,654**	**1,963**	**1,684**
Median	1,590	1,544	1,609	1,590

*Only the average is weighted.

Figure 10-2 shows total CFM50 by home size; as shown, total leakage varies widely for homes of similar size.

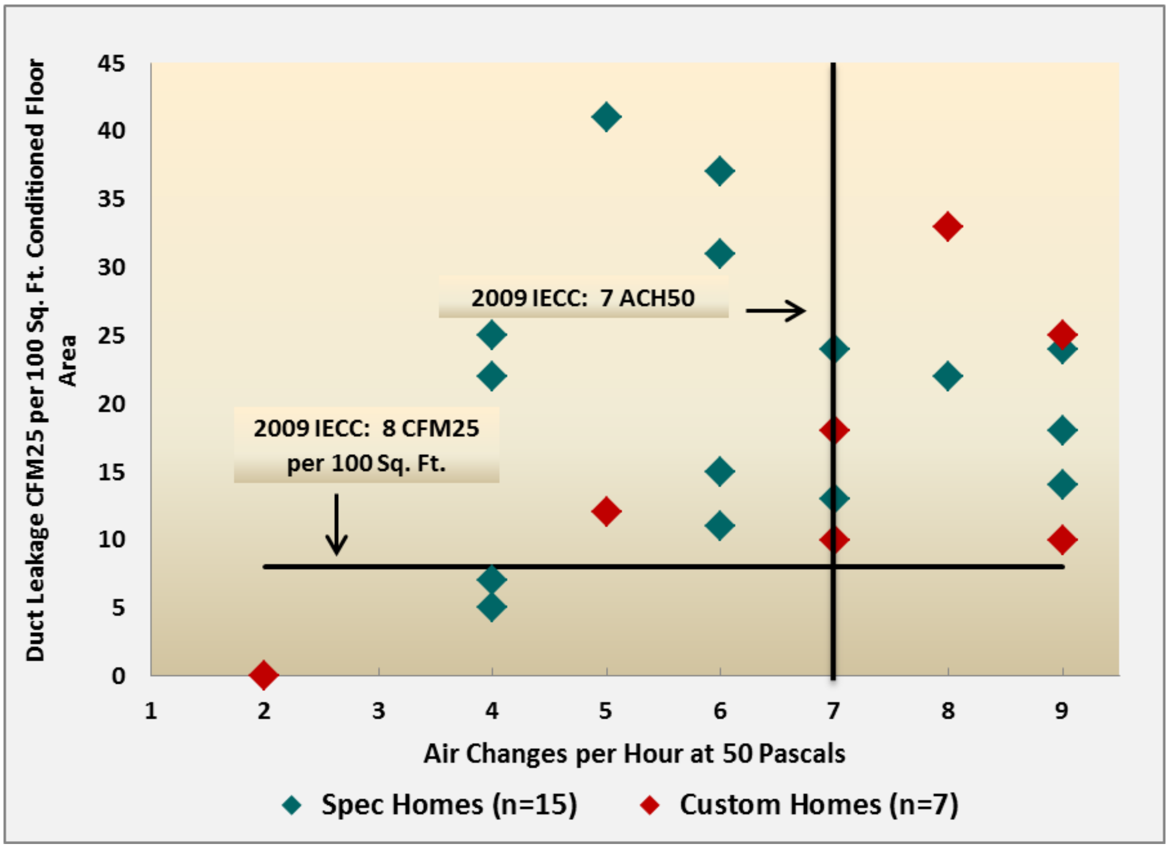
Figure 10-2: Total CFM50 Leakage by Home Size



10.1 Air Infiltration and Duct Leakage

Many tight homes have leaky ducts. Figure 10-3 shows air infiltration and duct leakage levels for the 22 homes with both air infiltration and duct leakage data. Three homes (lower left) meet 2009 IECC requirements for both duct leakage and air infiltration. Over one-half of the homes, 12 homes, (upper left) meet the 2009 IECC air infiltration requirement but not the duct leakage requirement. Seven homes (upper right) do not meet either the 2009 IECC duct leakage or air infiltration requirements. No homes meet the 2009 IECC duct leakage requirement, but not the air infiltration requirement.

Figure 10-3: Air Infiltration and Duct Leakage



11 Lighting

Auditors collected information on the total number and types of light bulbs (including fluorescent tubes) in each fixture and ceiling fan in each of 38 homes visited.[50] In addition to establishing a baseline, these data were used to determine that only 8% of the 38 homes visited, on a weighted basis, would be in compliance with the 2009 IECC requirement to have a minimum of 50% of the lamps in permanently installed lighting fixtures be high-efficacy lamps in homes complying through the prescriptive path. The 2006 IECC has no lighting requirement.

11.1 Lighting Counts from the On-Site Inspections

Auditors counted the numbers of the following types of light bulbs in each home: screw-in CFL bulbs, pin-based CFL bulbs, fluorescent tubes, and incandescent bulbs. For the purposes of this analysis, the first three are considered energy efficient. Weighted results show that close to two-thirds (64%) of the homes visited have very few energy-efficient bulbs installed, accounting for 10% or less of all bulbs installed in the home. Only 8% (weighted and unweighted) of the homes visited have 50% or more of their bulbs classified as energy efficient and would be in compliance with the 2009 IECC prescriptive compliance path lighting requirement. Seven percent of the homes visited, on a weighted basis, have 75% or more of their fixtures fitted with bulbs classified as energy efficient and would be in compliance with 2012 IECC (Table 11-1).

Table 11-1: Portion of Homes with Fixtures Containing Energy-Efficient Bulbs

Percent of Energy-Efficient Bulbs in the Home	All Homes (n=38)	Spec Homes (n=24)	Custom Homes (n=14)	Weighted (Spec/ Custom)
10% or less	26 (68%)	15 (62%)	11 (79%)	64%
11% to 30%	6 (16%)	4 (17%)	2 (14%)	17%
30% to 49%	3 (8%)	3 (13%)	0 (0%)	12%
Compliance with 2009 IECC (50% or more energy efficient)				
50% to 74%	1 (3%)	0 (0%)	1 (7%)	1%
75% to 100%	2 (5%)	2 (8%)	0 (0%)	7%

[50] The auditors collected only fixture information for two homes; these homes were excluded from the analyses since the number of bulbs installed was not known and could thus not be compared with other homes where the number and type of all bulbs were counted. These two homes had total fixture counts of 26 and 52; of these fixtures, 42% and 58%, respectively, had energy-efficient bulbs installed.

Similar analyses of the percentages of energy-efficient bulbs in the home and whether the home would be in compliance with 2009 IECC were performed for the 34 homes where the homeowner answered the question of who specified the lighting in the home. The home owner first indicated whether the builder/architect or home owner chose what was installed; in the case of the later, the respondents were also asked if they chose from a list of options or could install any type of lighting they wanted. As Table 11-2 shows, owners who could choose any lighting they wanted had the smallest proportion of energy-efficient bulbs, but the difference is not statistically significant, at the 90% confidence level.

Table 11-2: Portion of Homes with Energy-Efficient Bulbs by Decision Maker

Percent of Energy-Efficient Bulbs in the Home	All Homes (n=34)	Owner Chose Lighting (n=20)	Owner Chose Lighting from Options (n=7)	Builder Chose Lighting (n=7)
10% or less	26 (76%)	17 (85%)	4 (57%)	5 (71%)
11% to 30%	5 (15%)	3 (15%)	1 (14%)	1 (14%)
30% to 49%	1 (3%)	0 (0%)	1 (14%)	0 (0%)
Compliance with 2009 IECC (50% or more energy efficient)				
50% to 74%	1 (3%)	0 (0%)	1 (14%)	0 (0%)
75% to 100%	1 (3%)	0 (0%)	0 (0%)	1 (14%)

Looking at the total number of bulbs counted in visited homes, weighted results show that only an average of 16% are energy-efficient.[51] Spec homes have a higher proportion and a higher average of energy-efficient bulbs than custom homes as well as being more likely to have CFL bulbs rather than fluorescent tubes, but these differences are not statistically significant. All homes have a weighted average of 9.1 energy-efficient bulbs, but the median is only 3.0 energy-efficient bulbs because relatively few homes account for the bulk of energy-efficient bulbs installed. (Table 11-3)

[51] An alternative methodology for calculating the percentage of energy-efficient bulbs is to first determine the percentage of energy-efficient bulbs in each home and then calculate the average of those percentages across all homes; this methodology is intended to avoid having very large or small homes bias results. However, using this methodology, the weighted average percentage of energy-efficient bulbs across all homes is only slightly lower at 15% versus 16%. The average percentage of energy-efficient bulbs in spec homes is 16% and in custom homes is 10%.

Table 11-3: Types of Bulbs Installed—All Homes

Number of Bulbs Installed in All Homes	All Homes (n=38)	Spec Homes (n=24)	Custom Homes (n=14)	Weighted (Spec/ Custom)
Average number of screw-in or pin-based CFL bulbs	5.9	7.7	2.8	7.2
Average number of fluorescent tubes	2.5	1.6	4.1	1.9
Average number of energy-efficient bulbs	8.4	9.3	6.9	9.1
Median number of energy-efficient bulbs	3.0	2.0	4.0	n/a
Average number of total bulbs	63.8	56.0	77.2	58.1
Average percent of total bulbs that are energy efficient	13%	17%	9%	16%

The analysis was rerun to exclude 10 homes that had only incandescent bulbs installed. It may be assumed that either the builders did not install any energy-efficient bulbs or the home owners replaced any energy-efficient bulbs that were installed in these 10 homes. Thus, excluding these 10 homes provides an analysis of the percentages of energy-efficient bulbs in homes that have at least one energy-efficient bulb installed. When looking at the 28 homes that had at least one energy-efficient bulb installed, the weighted average percentage of energy-efficient bulbs per home is only a bit higher at 21% versus 16% for all homes (Table 11-4). Again, spec homes have a higher average proportion and a higher average number of energy-efficient bulbs than custom homes but the differences are not statistically significant. It is interesting to note, however, that custom homes in this subgroup have significantly more total bulbs than spec homes.[52]

Table 11-4: Types of Bulbs Installed—Homes with One or More Energy-Efficient Bulb

Number of Bulbs Installed in All Homes	All Homes (n=28)	Spec Homes (n=17)	Custom Homes (n=11)	Weighted* (Spec/ Custom)
Average number of screw-in or pin-based CFL bulbs	8.0	10.9	3.5	10.2
Average number of fluorescent tubes	3.4	2.2	5.3	2.5
Average number of energy-efficient bulbs	11.5	13.2	8.8	12.8
Median number of energy-efficient bulbs	6.0	6.0	6.0	n/a
Average number of total bulbs	72.0	**61.1***	**88.9***	63.9
Average percent of total bulbs that are energy efficient	16%	22%	10%	21%

*Custom homes are significantly different from spec homes at the 90% confidence level.

[52] Not surprisingly, custom homes with one or more energy-efficient bulbs are significantly larger than corresponding spec homes with 2,931 square feet of space versus 2,054 square feet.

Table 11-5 summarizes saturation of energy-efficient bulbs by the major room types. Because not every home contains the same room types, saturations were calculated based only on those homes where the room type was present. Saturations by room type are calculated as averages of the percentages of energy-efficient bulbs in the particular room.

It is worth noting that utility rooms, basements, and garages (though the latter had a very small sample) are the most likely to contain energy-efficient bulbs, while family rooms or dens, outdoors areas, dining rooms, and living rooms are the least likely to contain energy-efficient bulbs. There is thus some evidence that energy-efficient bulbs tend to be installed in relatively low use areas.

Table 11-5: Average Number and Percent of Energy-Efficient Bulbs by Room

Rooms	All Homes		Spec Homes		Custom Homes		Weighted Average Percent of Energy-Efficient Bulbs per Home in each Room
	Number of Homes	Average Percent of Energy-Efficient Bulbs per Home in each Room	Number of Homes	Average Percent of Energy-Efficient Bulbs per Home in each Room	Number of Homes	Average Percent of Energy-Efficient Bulbs per Home in each Room	
Bathroom	38	12%	24	14%	14	8%	13%
Bedroom	37	16%	24	19%	13	9%	18%
Kitchen	36	12%	23	16%	13	5%	15%
Hallway	35	16%	21	20%	14	10%	19%
Outdoor	32	3%	20	2%	12	4%	2%
Living Room	29	9%	20	11%	9	4%	11%
Basement	23	19%	13	26%	10	10%	24%
Utility Room	22	34%	14	30%	8	41%	31%
Dining Room	20	7%	15	9%	5	0%	8%
Foyer	17	9%	11	14%	6	0%	13%
Family Room or Den	9	0%	4	0%	5	0%	0%
Garages	8	50%	4	25%	4	75%	30%

11.2 Ceiling Fans

Weighted results show that about two-thirds (66%) of the homes visited have at least one ceiling fan. As Table 11-6 shows, homes that have ceiling fans are most likely to have four or fewer fans; a few homes have five or more ceiling fans.

Table 11-6: Homes with Ceiling Fans

Number of Ceiling Fans	All Homes (n=38)	Spec Homes (n=24)	Custom Homes (n=14)	Weighted (Spec/Custom)
Zero	12 (32%)	8 (33%)	4 (29%)	33%
One	7 (18%)	4 (17%)	3 (21%)	17%
Two	2 (5%)	2 (8%)	0 (0%)	7%
Three	3 (8%)	1 (4%)	2 (14%)	5%
Four	7 (18%)	6 (25%)	1 (7%)	23%
Five	3 (8%)	2 (8%)	1 (7%)	8%
Six	3 (8%)	1 (4%)	2 (14%)	5%
Seven or more	1 (3%)	0 (0%)	1 (7%)	1%

12 Appliances

Auditors collected detailed information on refrigerators, both primary and secondary, dishwashers, and clothes washers.[53] Limited information was also collected for clothes dryers and cooking ranges. There are no appliance requirements for 2006 IECC or 2009 IECC compliance.

12.1 Refrigerators

Auditors recorded refrigerator information on the ENERGY STAR status, condition, age, type, and size. Weighted results show that more than five out of six (84%) primary refrigerators are ENERGY STAR (Table 12-1).

Table 12-1: ENERGY STAR Status for Primary Refrigerators

Status	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=14)	Weighted (Spec/Custom)
ENERGY STAR	32 (80%)	22 (85%)	10(71%)	84%
Not ENERGY STAR	8 (20%)	4 (15%)	4 (29%)	16%

Bottom freezer and side-by-side models are the most common with each accounting for approximately two out of five primary refrigerators. As might be expected, almost all of the primary refrigerators in the new homes inspected are considered to be in good condition (Table 12-2).

Table 12-2: Primary Refrigerator Type and Condition

Type	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=14)	Weighted (Spec/Custom)
Bottom freezer	18 (45%)	10 (38%)	8 (57%)	40%
Side-by-side	15 (37%)	10 (38%)	5 (36%)	38%
Top freezer	5 (13%)	5 (19%)	0 (0%)	17%
Single Door	2 (5%)	1 (4%)	1 (7%)	4%
Condition				
Good	39 (98%)	25 (96%)	14 (100%)	96%
Fair	1 (2%)	1 (4%)	0 (0%)	4%

[53] Some information was collected on 40 primary refrigerators, 6 secondary refrigerators, 40 clothes washers, and 38 dishwashers; there were two homes that did not have a dishwasher at the time of the audits. Some parameters, such as age, type, size, condition, and ENERGY STAR status are missing values for a few of the homes visited; the number of homes included for each parameter is shown in the appropriate tables.

Weighted results show that nearly two-thirds (66%) of primary refrigerators are 23 cubic feet or larger; with nearly one-third (32%) being over 25 cubic feet (Table 12-3). All primary refrigerators which had their ages recorded (39) are new.

Table 12-3: Primary Refrigerator Size

Size	All Homes (n=34)	Spec Homes (n=22)	Custom Homes (n=12)	Weighted (Spec/Custom)
Under 20 cubic feet	5 (15%)	3 (14%)	2 (17%)	14%
20 to 22 cubic feet	8 (24%)	4 (18%)	4 (33%)	20%
23 to 25 cubic feet	13 (38%)	7 (32%)	6 (50%)	34%
Over 25 cubic feet	8 (24%)	8 (36%)	0 (0%)	32%

Six of the forty homes visited have secondary refrigerators. Weighted results show that two-thirds (67%) of these refrigerators are not ENERGY STAR. While all six were recorded as being in good condition, they do tend to be older and smaller than primary refrigerators. Most of these refrigerators are top-freezer models (Table 12-4).

Table 12-4: Secondary Refrigerator Characteristics

ENERGY STAR Status	All Homes (n=6)	Spec Homes (n=3)	Custom Homes (n=3)	Weighted (Spec/Custom)
ENERGY STAR	2 (33%)	1 (33%)	1 (33%)	33%
Not ENERGY STAR	4 (67%)	2 (67%)	2 (67%)	67%
Type				
Top freezer	5 (83%)	3 (100%)	2 (67%)	97%
Side-by-side	1 (17%)	0 (0%)	1 (33%)	3%
Size				
Under 20 cubic feet	5 (83%)	3 (100%)	2 (67%)	97%
Over 25 cubic feet	1 (17%)	0 (0%)	1 (33%)	3%
Age				
2 years or less	2 (33%)	1 (33%)	1 (33%)	33%
3 to 10 years	3 (50%)	1 (33%)	2 (67%)	36%
Over 10 years	1 (17%)	1 (33%)	0 (0%)	30%

12.2 Dishwashers

Auditors recorded dishwasher information on the ENERGY STAR status, condition, and age. Weighted results show that almost all (93%) dishwashers are ENERGY STAR (Table 12-5). As might be expected, all of the dishwashers that had their ages recorded (34) are new and all that had their conditions recorded (36) are considered to be in good condition.

Table 12-5: ENERGY STAR Status for Dishwashers

Status	All Homes (n=38)	Spec Homes (n=25)	Custom Homes (n=13)	Weighted (Spec/Custom)
ENERGY STAR	36 (95%)	23 (92%)	13 (100%)	93%
Not ENERGY STAR	2 (5%)	2 (8%)	0 (0%)	7%

12.3 Clothes Washers

Auditors recorded clothes washer information on the ENERGY STAR status, type, age, and condition. Nearly two-thirds (65% weighted and unweighted) of clothes washers in the homes audited are ENERGY STAR (Table 12-6). Weighted results show that just over one-half (51%) are front load models (Table 12-7). Again, all of the clothes washers that had their ages recorded (38) are new and all that had their conditions recorded (39) are considered to be in good condition.

Table 12-6: ENERGY STAR Status for Clothes Washers

Status	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=14)	Weighted (Spec/Custom)
ENERGY STAR	26 (65%)	17 (65%)	9 (64%)	65%
Not ENERGY STAR	14 (35%)	9 (35%)	5 (36%)	35%

Table 12-7: Clothes Washer Type

Type	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=14)	Weighted (Spec/Custom)
Front load	22 (55%)	13 (50%)	9 (64%)	51%
Top load	18 (45%)	13 (50%)	5 (36%)	49%

12.4 Other Appliances

The only information collected on clothes dryers is the fuel type. Weighted results show that more than seven out of ten (73%) clothes dryers use electricity; most of the rest use propane (Table 12-8).

Table 12-8: Clothes Dryer Fuel

Fuel	All Homes (n=37)	Spec Homes (n=23)	Custom Homes (n=14)	Weighted (Spec/Custom)
Electricity	26 (70%)	17 (74%)	9 (64%)	73%
Propane	6 (16%)	4 (17%)	2 (14%)	17%
Natural Gas	5 (14%)	2 (9%)	3 (21%)	10%

Information on type and fuel used was collected for cooking ranges. Weighted results show the vast majority (86%) of homes have combination cook top and oven ranges (Table 12-9). Just over one-third (37%) each use natural gas and electricity; just over one-quarter (26%) use propane (Table 12-10).

Table 12-9: Cooking Range Characteristics

Type	All Homes (n=40)	Spec Homes (n=26)	Custom Homes (n=14)	Weighted (Spec/Custom)
Combination cook top and oven	32 (80%)	23 (88%)	9 (64%)	86%
Separate cook top and stand-alone oven	8 (20%)	3 (12%)	5 (36%)	14%

Table 12-10: Cooking Range Fuel

Fuel	All Homes (n=39)	Spec Homes (n=25)	Custom Homes (n=14)	Weighted (Spec/Custom)
Natural Gas	15 (38%)	9 (36%)	6 (43%)	37%
Electricity	12 (31%)	10 (40%)	2 (14%)	37%
Propane	12 (31%)	6 (24%)	6 (43%)	26%

Appendix A Comparison to 2009 IECC Prescriptive Insulation Requirements by Site

Table A-1: Comparison to Prescriptive Requirements by Site

Site	Spec/ Custom Home	Wood Framed Wall Insulation R-20	Foundation Wall R-10/R-13 (cont./cavity)	Duct Insulation in Unconditioned Space R-8 Attic Supply Ducts R-6 all other Ducts	Ceiling Insulation R-38	Floor Insulation over Unconditioned Space	Applicable Prescriptive Requirements Met
1	Spec	Exceed	n/a	Exceed	Meet	Meet	4 out of 4
2	Custom	Exceed	Meet	n/a	Exceed	Meet	4 out of 4
3	Spec	Exceed	Fail	Fail	Meet	Meet	3 out of 5
4	Custom	Fail	n/a	Exceed	Meet	Meet	3 out of 4
5	Spec	Fail	n/a	Exceed	Exceed	Meet	3 out of 4
6	Custom	Exceed	Exceed	n/a	Fail	Exceed	3 out of 4
7	Spec	Exceed	n/a	Exceed	Fail	Exceed	3 out of 4
8	Spec	Fail	Exceed	Fail	Fail	Meet	2 out of 5
9	Spec	Fail	Exceed	Fail	Fail	Meet	2 out of 5
10	Custom	Fail	n/a	Fail	Meet	Meet	2 out of 4
11	Spec	Fail	Fail	n/a	Meet	Meet	2 out of 4
12	Custom	Fail	n/a	Fail	Exceed	Meet	2 out of 4
13	Custom	Fail	n/a	Exceed	Meet	Fail	2 out of 4
14	Spec	Fail	n/a	Meet	Fail	Meet	2 out of 4
15	Custom	Exceed	n/a	n/a	Meet	Fail	2 out of 3
16	Spec	Fail	n/a	n/a	Meet	Meet	2 out of 3
17	Spec	Fail	n/a	Fail	Meet	Fail	1 out of 4
18	Spec	Fail	n/a	Fail	Meet	Fail	1 out of 4
19	Spec	Fail	n/a	Fail	Meet	Fail	1 out of 4
20	Spec	Fail	Fail	n/a	Fail	Meet	1 out of 4
21	Spec	Fail	n/a	Exceed	Fail	Fail	1 out of 4
22	Custom	Fail	n/a	Fail	Meet	Fail	1 out of 4
23	Spec	Fail	n/a	Fail	Meet	Fail	1 out of 4
24	Spec	Fail	n/a	Fail	Meet	Fail	1 out of 4
25	Spec	Fail	n/a	Exceed	Fail	Fail	1 out of 4
26	Spec	Fail	n/a	Fail	Meet	Fail	1 out of 4
27	Custom	Exceed	n/a	Fail	Fail	Fail	1 out of 4
28	Spec	Fail	n/a	n/a	Meet	Fail	1 out of 3
29	Spec	Meet	n/a	n/a	Fail	Fail	1 out of 3
30	Custom	Exceed	n/a	n/a	Fail	Fail	1 out of 3

Site	Spec/ Custom Home	Wood Framed Wall Insulation R-20	Foundation Wall R-10/R-13 (cont./cavity)	Duct Insulation in Unconditioned Space R-8 Attic Supply Ducts R-6 all other Ducts	Ceiling Insulation R-38	Floor Insulation over Unconditioned Space	Applicable Prescriptive Requirements Met
31	Spec	Fail	n/a	n/a	Meet	Fail	1 out of 3
32	Custom	Fail	n/a	Fail	Fail	Fail	0 out of 4
33	Spec	Fail	n/a	DK	Fail	Fail	0 out of 4
34	Spec	Fail	n/a	Fail	Fail	Fail	0 out of 4
35	Spec	Fail	n/a	n/a	Fail	Fail	0 out of 3
36	Spec	Fail	n/a	n/a	Fail	Fail	0 out of 3
37	Custom	Fail	n/a	n/a	Fail	Fail	0 out of 3
38	Custom	Fail	n/a	n/a	Fail	Fail	0 out of 3
39	Custom	Fail	n/a	n/a	Fail	Fail	0 out of 3
40	Spec	Fail	n/a	n/a	Fail	Fail	0 out of 3

Appendix B Code Compliance Details

This appendix provides additional details on the checklist, annual energy cost, and UA trade-off compliance paths. Table B-1 displays detailed checklist compliance results for all 63 checklist items. The left column displays checklist item and within that column the number in parentheses represents the number of points each item represents (i.e., 1, 2, or 3 points).

Table B-1: Compliance with IECC Prescriptive Insulation Requirements

Item (PNNL points in Parentheses)	Component Group	Code Requirement	n	All Homes (n = 40)	Spec (n = 26)	Custom (n = 14)	Weighted Data
Construction drawings and documentation available. Documentation sufficiently demonstrates energy code compliance. (3)	Other		6	2 (33%)	1 (50%)	1 (25%)	48%
HVAC loads calculations Heating system size(s): (2)	Other			N/A	N/A	N/A	N/A
Slab edge insulation R-value: R-10 unheated, R-15 heated (3)	Slab	R-10 unheated, R-15 heated	4	3 (75%)	1 (100%)	2 (67%)	97%
Slab edge insulation Installed per manufacturer's instructions. (3)	Slab			N/A	N/A	N/A	N/A
Slab edge insulation depth/length: 2 ft (3)	Slab	2 ft	2	2 (100%)	N/A	2 (100%)	N/A
Basement wall exterior insulation R-value2: (3)	Walls	R-10, continuous	3	2 (67%)	1 (50%)	1 (100%)	55%
Basement wall exterior insulation installed per manufacturer's instructions. (3)	Walls		2	2 (100%)	1 (100%)	1 (100%)	100%
Basement wall exterior insulation depth. (3)	Walls	10 ft or to basement floor	2	1 (50%)	0 (0%)	1 (100%)	10%
Crawl space wall insulation R-value. (3)	Crawl Space	R-10 continuous, R-13 cavity		N/A	N/A	N/A	N/A
Crawl space wall insulation installed per manufacturer's instructions. (3)	Crawl Space			N/A	N/A	N/A	N/A

Item (PNNL points in Parentheses)	Component Group	Code Requirement	n	All Homes (n = 40)	Spec (n = 26)	Custom (n = 14)	Weighted Data
Crawl space continuous vapor retarder installed with joints overlapped by 6 inches and sealed, and extending at least 6" up the stem wall. (3)	Crawl Space			N/A	N/A	N/A	N/A
Exposed foundation insulation protection. (2)	Other		1	1 (100%)	N/A	1 (100%)	N/A
Snow melt controls. (2)	Other			N/A	N/A	N/A	N/A
Door U-factor.3 (3)	Doors	U-0.35	8	8 (100%)	7 (100%)	1 (100%)	100%
Glazing U-factor (area-weighted average).4 (3)	Windows	U-0.35 (0.48 max)	11	11 (100%)	8 (100%)	3 (100%)	100%
Glazing SHGC value, including sunrooms (area-weighted average).4 (3)	Windows			N/A	N/A	N/A	N/A
Glazing labeled for U-factor (or default values used). (3)	Windows		2	2 (100%)	2 (100%)	N/A	N/A
Skylight U-factor.4 (3)	Windows	U-06 (0.75 max)	2	2 (100%)	1 (100%)	1 (100%)	100%
Skylight SHGC value.4 (3)	Windows			N/A	N/A	N/A	N/A
Skylights labeled for U-factor (or default values used). (3)	Windows		1	1 (100%)	1 (100%)	N/A	N/A
Sunroom glazing U-factor. (3)	Windows	U-0.5		N/A	N/A	N/A	N/A
Sunroom skylight U-factor. (3)	Windows	U-0.75		N/A	N/A	N/A	N/A
Mass wall exterior insulation R-value. (3)	Walls	R-13		N/A	N/A	N/A	N/A
Mass wall exterior insulation installed per manufacturer's instructions. (3)	Walls	R-8 Attic Supply, R-6 Other		N/A	N/A	N/A	N/A
Duct insulation. (3)	Ducts	6 CFM across system, 4 CFM no air handler	26	11 (42%)	7 (41%)	4 (44%)	42%

Item (PNNL points in Parentheses)	Component Group	Code Requirement	n	All Homes (n = 40)	Spec (n = 26)	Custom (n = 14)	Weighted Data
Duct sealing complies with listed sealing methods. (3)	Ducts		7	2 (29%)	1 (17%)	1 (100%)	25%
Duct tightness via rough-in test. If applicable, verification via post-construction test should be marked N/A. (3)	Ducts	6 CFM across system, 4 CFM no air handler		N/A	N/A	N/A	N/A
Building cavities NOT used for supply ducts. (3)	Ducts		15	15 (100%)	10 (100%)	5 (100%)	100%
IC-rated recessed lighting fixtures meet infiltration criteria. (2)	Air Sealing		7	7 (100%)	4 (100%)	3 (100%)	100%
HVAC piping insulation. (2)	Other	R-3	39	1 (3%)	1 (4%)	0 (0%)	3%
Circulating hot-water piping insulation. (2)	Plumbing Penetrations	R-2	2	0 (0%)	N/A	0 (0%)	N/A
Dampers Installed on all outdoor Intake and exhaust openings. (2)	Fans and Vents		40	40 (100%)	26 (100%)	14 (100%)	100%
Glazed fenestration air leakage. (1)	Air Sealing	0.3 cfm/ft2		N/A	N/A	N/A	N/A
Swinging door air leakage. (1)	Air Sealing	0.5 cfm/ft2		N/A	N/A	N/A	N/A
Fenestration and doors labeled for air leakage. (1)	Air Sealing			N/A	N/A	N/A	N/A
Floor insulation R-value. (3)	Floors	R-30 Wood, Floor steel frame equivalent: R-19+R-6 in 2x6 or R-19+R-12 in 2x8 or 2x10	37	18 (49%)	14 (58%)	4 (31%)	56%
Floor insulation installed per manufacturer's instructions, and in substantial contact with the subfloor. (3)	Floors		28	19 (68%)	11 (69%)	8 (67%)	69%
Wall insulation R-value. (3)	Walls	Wood:R-20 or 13+5, Mass: R-17, Wall steel frame equivalent: R-	40	20 (50%)	13 (50%)	7 (50%)	50%

Item (PNNL points in Parentheses)	Component Group	Code Requirement	n	All Homes (n = 40)	Spec (n = 26)	Custom (n = 14)	Weighted Data
		13+R-10; R-19+R-9; R-25+R-8					
Wall insulation installed per manufacturer's instructions. (3)	Walls		27	25 (93%)	15 (94%)	10 (91%)	93%
Basement wall interior insulation R-value. (3)	Walls	Continuous: R-10, Cavity: R-13	5	3 (60%)	2 (50%)	1 (100%)	55%
Basement wall interior insulation installed per manufacturer's Instructions. (3)	Walls		4	4 (100%)	3 (100%)	1 (100%)	100%
Basement wall interior insulation depth. (3)	Walls	10 ft or to basement floor	4	4 (100%)	3 (100%)	1 (100%)	100%
Sunroom wall insulation R-value. (3)	Walls	R-13		N/A	N/A	N/A	N/A
Sunroom wall insulation installed per manufacturer's Instructions. (3)	Walls		1	0 (0%)	N/A	0 (0%)	N/A
Sunroom ceiling insulation R-value. (3)	Ceilings	R-24		N/A	N/A	N/A	N/A
Sunroom ceiling insulation installed per manufacturer's instructions. (3)	Ceilings			N/A	N/A	N/A	N/A
Air sealing complies with sealing requirements via blower door test. If applicable, verification via visual inspection should be marked N/A. (3)	Air Sealing	ACH 50 ≤ 7	40	30 (75%)	21 (81%)	9 (64%)	79%
All installed insulation labeled or installed R-value provided. (2)	Other		2	2 (100%)	1 (100%)	1 (100%)	100%

Item (PNNL points in Parentheses)	Component Group	Code Requirement	n	All Homes (n = 40)	Spec (n = 26)	Custom (n = 14)	Weighted Data
Air sealing of all openings and penetrations via visual inspection: • Site-built fenestration • Window/door openings • Utility penetrations • Attic access openings If applicable, verification via blower door should be marked N/A. (1)	Air Sealing			N/A	N/A	N/A	N/A
Air sealing of all envelope joints and seams via visual inspection: Dropped ceilings Knee walls Assemblies separating garage Tubs and showers Common walls between units Rim joist junctions, If applicable, verification via blower door should be marked N/A. (1)	Air Sealing			N/A	N/A	N/A	N/A
Air sealing of all other sources of infiltration, including air barrier, via visual inspection. If applicable, verification via blower door should be marked N/A. (1)	Air Sealing			N/A	N/A	N/A	N/A
Ceiling insulation R-value. (3)	Ceilings	Wood: R-38, Steel truss equivalent: R-49; R-38+R-3	40	27 (68%)	20 (77%)	7 (50%)	74%
Ceiling insulation installed per manufacturer's instructions. Blown insulation marked every 300 ft2. (3)	Ceilings		39	33 (85%)	22 (88%)	11 (79%)	87%
Attic access hatch and door insulation. (3)	Doors	R-38	32	17 (53%)	13 (54%)	4 (50%)	54%

Item (PNNL points in Parentheses)	Component Group	Code Requirement	n	All Homes (n = 40)	Spec (n = 26)	Custom (n = 14)	Weighted Data
Duct tightness via post-construction test. If applicable, verification via rough-in test should be marked N/A. (3)	Ducts	To Outdoors: 8 cfm	25	5 (20%)	4 (22%)	1 (14%)	21%
Heating and cooling equipment type and capacity as per plans. (3)	Other			N/A	N/A	N/A	N/A
Lighting - 50% of lamps are high efficacy. (3)	Lighting		38	3 (8%)	2 (8%)	1 (7%)	8%
Certificate posted. (2)	Other		40	2 (5%)	1 (4%)	1 (7%)	4%
Wood burning fireplace - gasketed doors and outdoor air for combustion. (2)	Fireplace		7	4 (57%)	2 (67%)	2 (50%)	65%
Programmable thermostats installed on forced air furnaces. (2)	Other		20	14 (70%)	10 (67%)	4 (80%)	68%
Heat pump thermostat installed on heat pumps. (2)	Other		1	1 (100%)	N/A	1 (100%)	N/A
Circulating service hot water systems have automatic or accessible manual controls. (2)	Other		2	2 (100%)	N/A	2 (100%)	N/A
Pool heaters, covers, and automatic or accessible manual controls. (2)	Other		3	3 (100%)	2 (100%)	1 (100%)	100%

Table B-2 breaks out spec and custom homes and compares the annual energy cost for the IECC 2009 reference to the cost across the inspected homes. Spec homes have total annual energy costs that are 24% greater than the reference home, while custom homes have costs that are 30% greater than the reference home. For each end use, custom homes have higher annual energy costs, relative to the reference home.

Table B-2: Annual Energy Cost by Home Type and End Use

End Use	Unweighted Average (n = 40)		Spec (n = 26)		Custom (n = 14)		Weighted Average	
	Reference	Design	Reference	Design	Reference	Design	Reference	Design
Heating	$1,851	$2,530	$1,617	$2,183	$2,285	$3,174	$1,684	$2,282
Cooling	$207	$208	$214	$208	$194	$208	$212	$208
Domestic Hot Water	$473	$469	$459	$452	$499	$501	$463	$457
Overall	**$2,531**	**$3,208**	**$2,290**	**$2,844**	**$2,979**	**$3,883**	**$2,359**	**$2,948**

Table B-3 breaks out the average UA values by component and home type. On average, weighted overall UA values exceed reference UA values by 42%.

Table B-3: Average UA Values by Component and Home Type

Component	Unweighted Average (n = 40)		Spec (n = 26)		Custom (n = 14)		Weighted Average	
	Reference	Design	Reference	Design	Reference	Design	Reference	Design
Ceiling	47.1	73.3	41.8	67.3	56.9	84.7	49.3	69.0
Above Grade Wall	110.8	140.6	107.2	143.6	117.4	135.0	108.2	142.7
Floors Over Garage	15.4	37.5	12.9	18.4	19.4	68.1	13.5	23.4
Floors Over Ambient	1.2	1.7	0.9	1.8	1.7	1.7	1.0	1.8
Floors Over Unconditioned Basement	44.6	160.7	41.2	165.1	54.5	148.1	42.5	163.4
Floors Over Unconditioned Crawlspace	43.7	66.5	33.2	41.3	49.0	79.1	34.7	45.0
Foundation Walls	33.4	62.2	18.1	61.6	71.8	63.6	23.4	61.8
Overall	**353.7**	**505.5**	**329.2**	**502.4**	**399.4**	**511.1**	**336.2**	**503.3**

*Overall does not equal sum of components because this table does not present every component and not every home had every component.

Appendix C Insulation Grades

The Residential Energy Services Network (RESNET) provides guidelines and definitions for defining the quality of insulation installation. RESNET has specified three grades for designating the quality of insulation installation; the grades range from Grade I (the best) to Grade III (the worst). The RESNET definitions of Grade I, Grade II, and Grade III installation are provided below.[54]

Grade I: "“Grade I” shall be used to describe insulation that is generally installed according to manufacturer’s instructions and/or industry standards. A "Grade I" installation requires that the insulation material uniformly fills each cavity side-to-side and top-to-bottom, without substantial gaps or voids around obstructions (such as blocking or bridging), and is split, installed, and/or fitted tightly around wiring and other services in the cavity. To attain a rating of "Grade I," wall insulation shall be enclosed on all six sides, and shall be in substantial contact with the sheathing material on at least one side (interior or exterior) of the cavity…Occasional very small gaps are acceptable for “Grade I”… Compression or incomplete fill amounting to 2% or less, if the empty spaces are less than 30% of the intended fill thickness, are acceptable for “Grade I”."

Grade II: "”Grade II” shall be used to describe an installation with moderate to frequent installation defects: gaps around wiring, electrical outlets, plumbing and other intrusions; rounded edges or “shoulders”; or incomplete fill amounting to less than 10% of the area with 70% or more of the intended thickness (i.e., 30% compressed); or gaps and spaces running clear through the insulation amounting to no more than 2% of the total surface area covered by the insulation."

Grade III: "”Grade III” shall be used to describe an installation with substantial gaps and voids, with missing insulation amounting to greater than 2% of the area, but less than 5% of the surface area is intended to occupy. More than 5% missing insulation shall be measured and modeled as separate, uninsulated surfaces…"

Below are some examples of insulation installation and the corresponding grade applied by auditors. A brief description of the reasoning behind the grade designation is described for each example. Please note that these photographs were not all taken during the site visits for this study, and they are not meant to show the good and bad building practices observed during the site visits. Rather, these pictures are meant to provide visual examples of typical insulation installation grades.

[54] Residential Energy Services Network. (2006). *2006 Mortgage Industry National Home Energy Rating Systems Standards.* Oceanside, CA: Residential Energy Services Network.

Figure C-1 shows a conditioned attic with closed cell spray foam applied to the walls. This installation received a Grade I installation as the closed cell spray foam has little to no gaps, has no compression, and the cavity is enclosed on all six sides.[55]

Figure C-1: Grade I Closed Cell Spray Foam—Exterior Walls

Figure C-2 shows a Grade II install of unfaced fiberglass batts in a conditioned basement.[56] The insulation has gaps in the corners of certain bays and there is some compression—though relatively minor compression overall. The insulation is enclosed on all six sides (in most places), warranting a Grade II designation.

Figure C-2: Grade II Fiberglass Batts—Basement Walls

[55] In the case of spray foam, a cavity may be open to the attic and still receive a Grade I installation because the spray foam itself is an air barrier.
[56] The basement in this case was considered conditioned volume, not conditioned floor area.

Figure C-3 shows R-21 fiberglass batts in a 2x4 wall cavity. This installation automatically receives a Grade III designation due to the fact that the insulation is not enclosed on the vented attic side. According to the RESNET standards on Grade III installation, "This designation shall include wall insulation that is not in substantial contact with the sheathing on at least one side of the cavity, or wall insulation in a wall that is open (unsheathed) on one side and exposed to the exterior, ambient conditions or a vented attic or crawlspace."

Figure C-3: Grade III Fiberglass Batts—Attic Kneewalls

Figure C-4 shows a Grade II installation of fiberglass batts in a frame floor cavity. While the insulation has a fair amount of compression the gaps are minimal. The primary reason for the Grade II designation is that the fiberglass batts are in substantial contact with the subfloor. This example shows an installation that is right on the boundary of Grade II and Grade III installation. It should be noted that the bay with ductwork on the right side of the image would certainly represent a grade III installation with substantial gaps and compression.

Figure C-4: Grade II Fiberglass Batts—Frame Floor

Figure C-5 shows frame floor insulation that received a Grade III designation. The insulation has gaps, substantial compression in places, and is severely sagging in other places. The sagging insulation creates an air space between the insulation and the subfloor, which ultimately diminishes the insulating characteristics of the fiberglass batts.

Figure C-5: Grade III Fiberglass Batts—Frame Floor

Figure C-6 shows a Grade I installation of blown fiberglass in an attic. This received a Grade I designation as the fiberglass is blown in evenly, filling all of the cavities with no gaps or voids and little to no compression. In addition, this attic has baffles at the eaves, which is required for attic insulation to achieve a Grade I installation.

Figure C-6: Grade I Blown Fiberglass—Attic

Appendix D Building Practices—Examples from the Site Visits

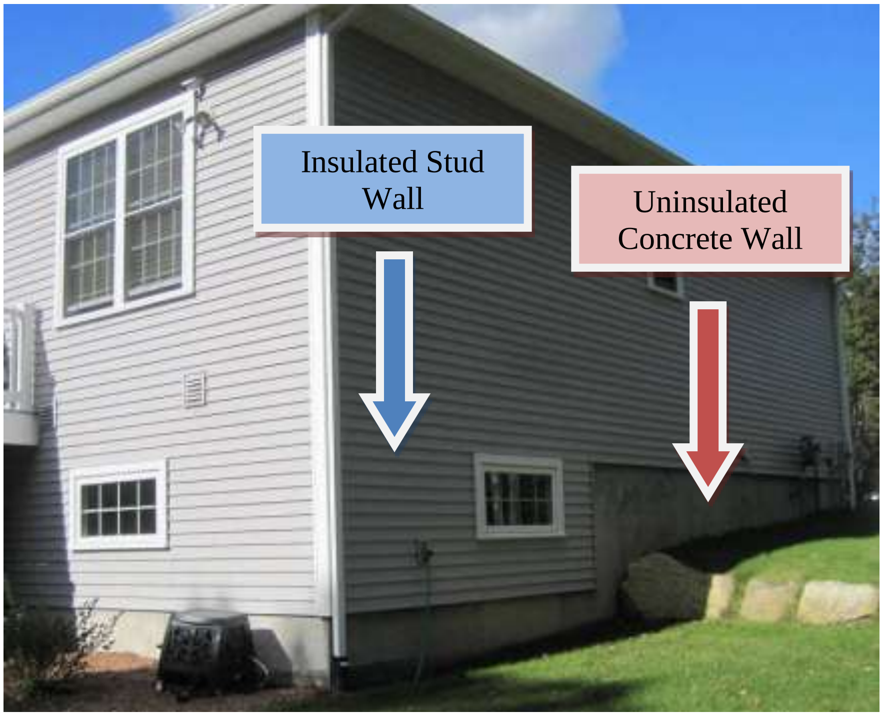
During their visits to new homes, auditors photographed examples of good building practices that contributed to a home's energy efficiency and poor building practices where the builder missed opportunities to improve the home's energy efficiency. Below are examples of the practices that auditors saw in homes, with photos and brief descriptions.

Foundation and Basement Walls

Builders rarely insulated foundation walls. Basements were typically unfinished and the concrete foundation walls were left uninsulated, even in walkout basements where a large percentage of the basement walls were above grade, insulated stud walls. (Note that by code, basement walls in unconditioned basements are not required to be insulated.)[57]

Figure D-1 shows a common instance of a home with uninsulated concrete foundation walls. Not installing rigid foam insulation on the foundation wall was a lost opportunity for energy savings and for making the basement more comfortable, particularly since the homeowner planned to finish this walkout basement. In addition, the above grade stud walls along the back and side of the basement were insulated, but the concrete foundation walls were not, even though much of these walls were above grade, just like the stud walls.

Figure D-1: Uninsulated Above Grade Foundation Walls



[57] It is common practice to insulate the stud walls on top of foundation walls in an unconditioned walkout basement. This gives homeowners the flexibility to easily finish such spaces in the future, adding to their conditioned floor area and useable living space.

Figure D-2 shows a walkout basement viewed from the inside. The above grade stud walls in this example were insulated with fiberglass batts (the white material is the plastic facing of the fiberglass batts themselves, serving as an air barrier). Above grade basement stud walls often had a separate, clear vinyl air barrier over the insulation, and frequently the insulation was not enclosed at all, degrading its insulating properties.

This arrangement of partially below grade concrete walls topped with insulated, above grade, framed walls was common in walkout basements, but, like in the example below, most builders did not insulate the concrete portion of the walls. The energy efficiency of such homes would always have been improved by bringing the basement fully into the thermal envelope because at least some of the mechanical equipment was always located in the basement, and homeowners often had plans to finish these walkout basements at some point in the future.

Figure D-2: Insulated Walkout Basement Walls

Slab Floors

Slab floors in basements were rarely insulated, either underneath or at their perimeter, meaning that the basement floor would always be cold in the winter. This was a lost opportunity in new homes whose homeowners planned to finish their basements, as these homeowners would have uncomfortable, cold floors in the basement for the life of the home.

Frame Floors

Fiberglass batt insulation in frame floors over basements (basement ceilings) was often poorly installed (and missing in some cases), with some exceptions.

In contrast, Figure D-3 shows an enclosed crawl space where the builder installed open cell spray foam between the wood I-beam floor joists over the crawl space. The foam was well installed, though not perfectly even – it was at least six inches thick, and a few inches thicker in some areas. The foam also insulated the rim joist area fully.

Figure D-3: Open Cell Foam Frame Floor Insulation over Crawl Space

Figure D-4 shows a builder trying to go the extra mile by using cavity and continuous insulation in a frame floor assembly, but running into problems during the actual installation of the insulation. In the photo, one can see the uninsulated concrete walls of a shallow crawlspace and the frame floor above. The frame floor cavities were insulated with fiberglass batts and the entire assembly was covered with reflective foam board as continuous insulation, most of which was installed reasonably well with minimal sagging, even if the joints of the foam board were not sealed. Mechanical penetrations interfered with a neat installation of the foam board across the entire frame floor; the foam was bent and sagging to accommodate mechanical lines running up into the frame floor cavities. The fiberglass cavity insulation was also falling out of the cavity where the foam board was starting to fall. More care could have been taken to create smaller cutouts in the foam board specifically for the mechanical penetrations, but certainly working in the shallow crawl space was a challenge for the contractor.

Figure D-4: Crawl Space Frame Floor with Sagging Foam Board Insulation

Figure D-5 shows a poor frame floor insulation installation. Fiberglass batts were sloppily installed over a walkout basement. The insulation was heavily compressed, installed unevenly, and in some cases sagging away from the subfloor. It was providing some benefit, but overall it was poorly installed. The pink fiberglass batt insulation visible on the above grade stud wall of the walkout basement also did not have an air barrier on the basement side, reducing the insulation's effectiveness.

Figure D-5: Poorly Installed Frame Floor Insulation

Figure D-6 shows another sloppy frame floor insulation installation, with large areas of missing insulation. The batts sagged down to, or past, the bottom flange of the wood I-beam floor joists, creating a large air space between the batts and the floor. Gaps, compression, and missing insulation to accommodate plumbing lines are also visible. HVAC and plumbing contractors not working in conjunction with insulation contractors often created such conflicts.

The contractor also cut a large hole in the subfloor below the bathtub for the insulation of plumbing lines, and this hole – nearly a square foot – had not been closed. The side of a panned floor joist return duct is also visible in the center of the photo; that had at least been sealed with a brush-on duct sealant.

Figure D-6: Missing Frame Floor Insulation & Holes in Subfloor

Rim Joists & Sealing Penetrations to the Outside

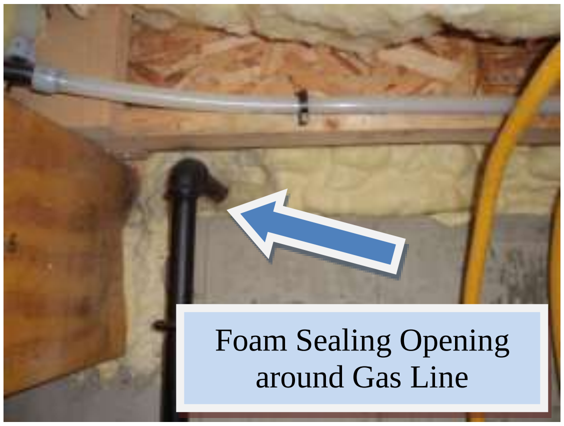
Rim joists were commonly insulated by the same fiberglass batts insulating the frame floors above basements, and builders did not consistently seal around HVAC, plumbing, electrical, or other penetrations to the outside of the house in the rim joist area. Builders often sealed utility penetrations individually with spray foam and then insulated the rim joist with fiberglass batts.

Figure D-7 shows a gap in the rim joist fiberglass batt insulation. The fiberglass batts were not properly fit around mechanical lines that ran outside, creating gaps in the insulation. The gaps around the utility penetrations were also not sealed, allowing air leakage into the basement.

Figure D-7: Uninsulated Rim Joist with Penetrations to Outside

Figure D-8, in contrast, shows spray foam insulating the rim joist and sealing gaps around penetrations to the outside, minimizing basement air leakage. Homes with spray foamed rim joists tended to perform quite well in blower door tests, though such homes may have had additional air sealing measures that auditors were not able to see so easily.

Figure D-8: Rim Joist Insulated with Spray Foam



Exterior Walls

Most homes had fiberglass batts as their exterior wall insulation, and as discussed previously, builders often did not consistently insulate basement walls, whether above or below grade.

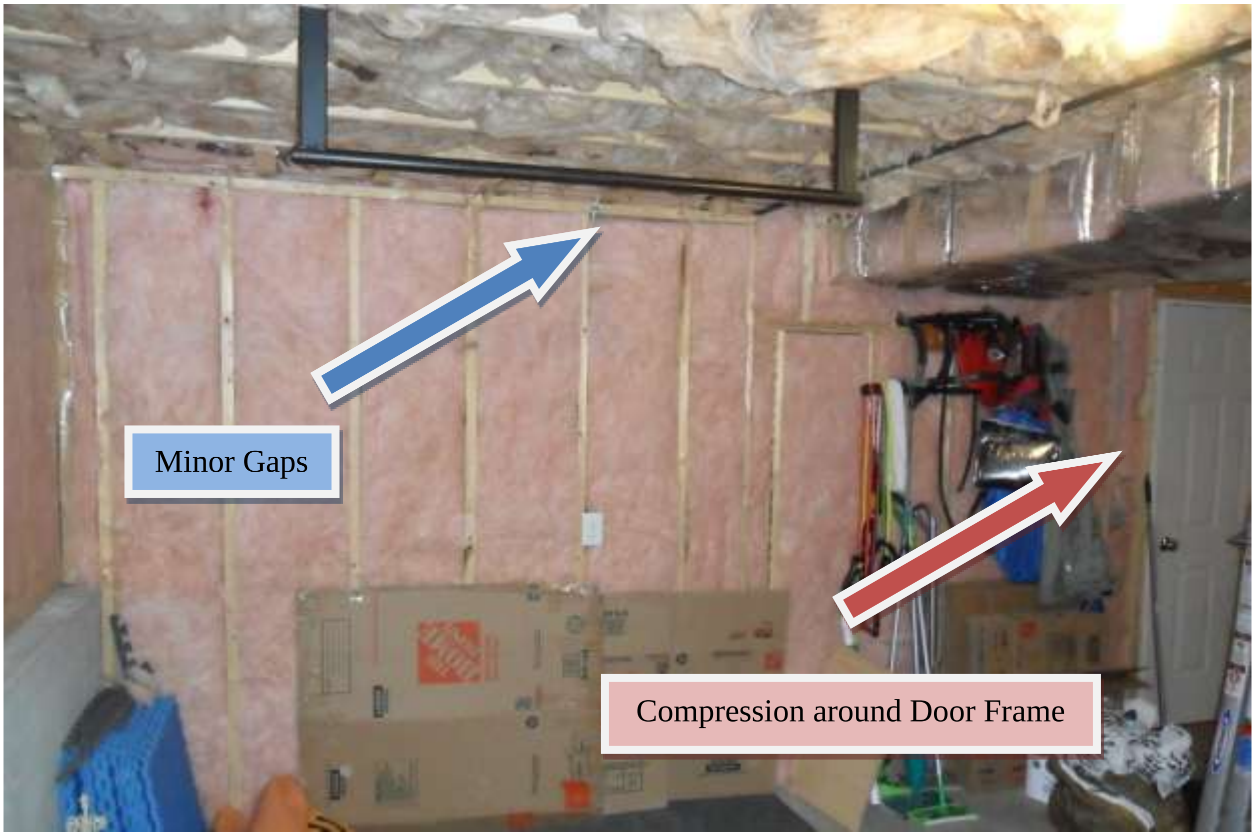
Figure D-9, in contrast, shows a home where the builder thoroughly insulated the walls, frame floor, and all roof rafters with closed cell spray foam, bringing the attic into the conditioned space of the home. This excellent insulation job serves as an example of foam that is well installed, with even thickness throughout, and also as an example of a builder going above and beyond, insulating every exterior surface of the home, minimizing unconditioned spaces. The photo below shows an unfinished upper level attic space, looking toward the inside of a dormer, with the sloping roof rafters visible.

The biggest improvement this builder could have made would have been insulating the crawl space walls rather than just the frame floor over the crawlspace, as there was HVAC equipment and leaky ductwork in the unconditioned crawl space (and in the insulated attic).

Figure D-9: Walls and Roof Rafters Insulated with Spray Foam

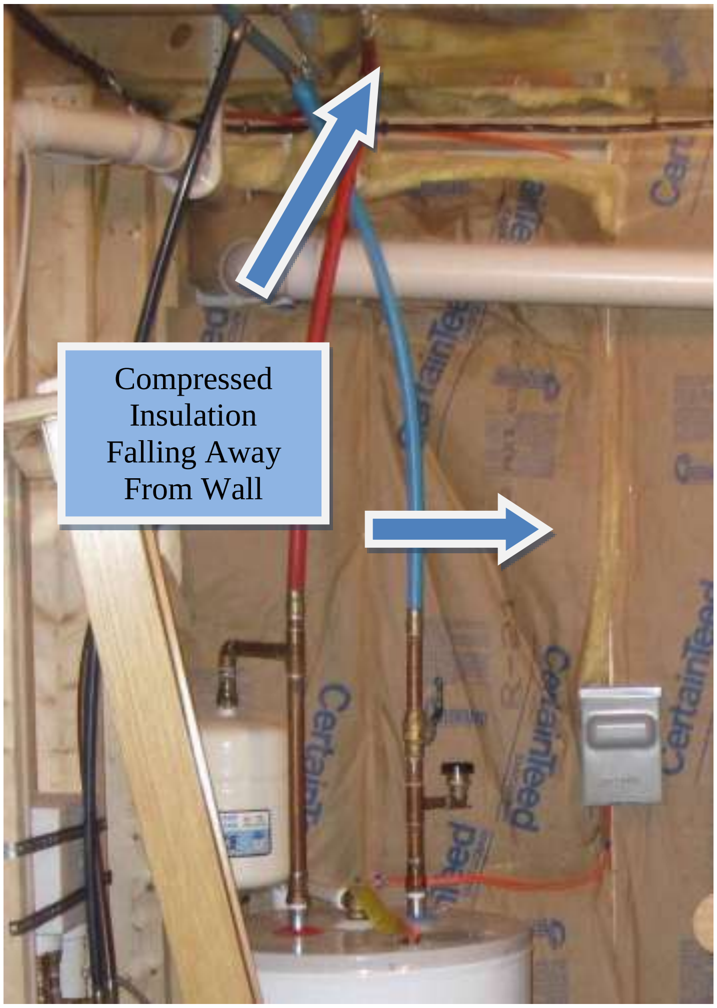
Figure D-10 shows the wall separating a basement from a garage. The fiberglass batts in this 2x4 wall were acceptably installed in that they were not compressed, but they had minor gaps, particularly around the door frame. This wall was missing an air barrier, however, greatly reducing the thermal performance of this wall. The extremely sloppy, sagging frame floor insulation is also visible in the upper part of the photo.

Figure D-10: Mostly Uncompressed Fiberglass Wall Insulation with no Air Barrier



Much like in Figure D-10, the below Figure D-11 shows a similar above grade basement wall with visible fiberglass batts, but the installation in the latter was worse. The R-21 batts were heavily compressed and starting to fall out of the cavity in some areas. The batts were clearly not cut to fit around electrical wiring, some of which appeared to be preventing the batts from sitting flush with the back of the cavity.

Figure D-11: Poorly Installed Fiberglass Wall Insulation with Gaps



Ceiling and Attic Insulation

Builders who use blown-in insulation in attics tended to achieve superior insulation installations to those who used fiberglass batts. They minimized insulation gaps, easily prevented thermal bridging by covering attic joists with insulation, and in some cases used the insulation to bury attic ducts. Most types of insulation were susceptible to compression, however, particularly if the HVAC contractors disturbed the attic insulation.

Figure D-12 shows an attic with poorly installed fiberglass batt insulation. There were significant gaps between batts, and batts had been stuffed to fit between oddly spaced ceiling joists and around mechanical systems, and sloppily installed in areas where the roof rafters were too low to work comfortably. This is certainly an instance of insulation and HVAC contractors not working in concert. Light is also visible at the edge of the attic, indicating missing wind baffles.

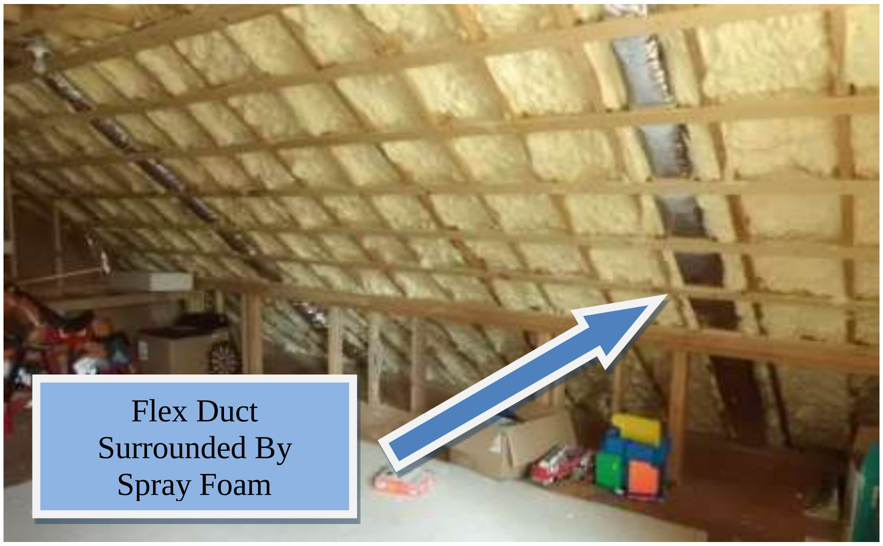
Figure D-12: Poorly Installed Fiberglass Batt Attic Insulation with Missing Wind Baffles

On the other hand, Figure D-13 shows a blown-in cellulose attic installation that did not have gaps and did use wind baffles, but was not evenly installed. There were peaks and valleys in the installation, particularly near the edges of the attic, where the insulation was a few inches thinner than the rest. Any increased thickness in some areas was more than offset by the underperformance of the areas with thin insulation.

Figure D-13: Uneven Attic Cellulose Installation

Figure D-14 shows a home where the builder installed spray foam in the roof rafters (and the attic walls). The foam brought the attic fully into the conditioned envelope, and because there was an HVAC system in this attic, duct leakage to the outside was reduced virtually to zero.

Figure D-14: Roof Rafters with Spray Foam Insulation



Similarly, Figure D-15 shows a homeowner attempting to bring the attic into conditioned space by insulating the roof rafters, but doing so with fiberglass batts rather than foam like in Figure D-14. The batts were mostly well installed, but the work was not finished – the batts ended a few feet above the soffit vents (light from outside is visible in the photo). It is unclear how the contractors would deal with the open soffit vents, as they would need to be closed for this new rafter insulation to condition the attic.

The attic floor was the original thermal boundary of the home. Shifting it to the roof line will bring the HVAC system into the conditioned envelope (if the insulation work is completed properly), which would be helpful since some of the ductwork was uninsulated and unsealed.

Figure D-15: Roof Rafters with Fiberglass Batts

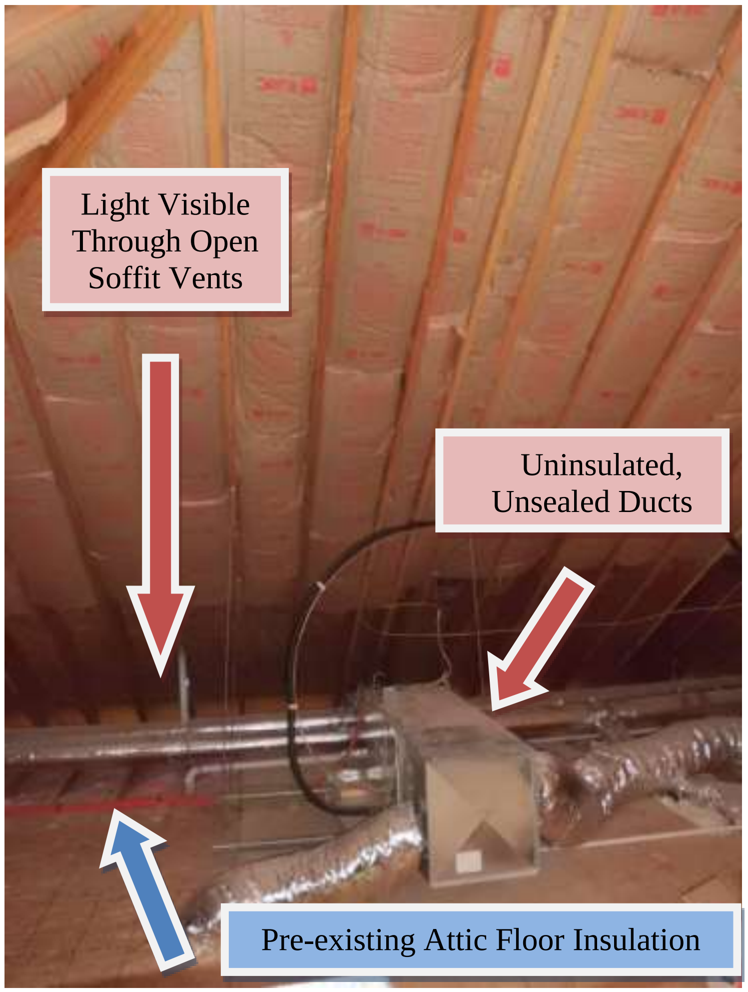


Figure D-16 shows a vented attic space separated from conditioned space by a short, sloppily insulated knee wall on the right. The builder used R-21 fiberglass batts in a 2x4 cavity, meaning much of the insulation stuck out past the cavity, providing little benefit. Much of the insulation was also compressed by the PVC pipe visible on the right, and there was no air barrier on the insulation. Wind could blow directly into the soffit vents on the left, wind washing the exposed fiberglass batts on the right. Fortunately, there was no ductwork in this attic space, as the home used hydronic heat.

Figure D-16: Knee Wall Insulation Exposed to Wind Washing

Figure D-17 shows a sloppy fiberglass batt installation separating a conditioned space (a wall in a room with a cathedral ceiling) from the attic. Much of the insulation had compression and large gaps, and some was falling out of the cavities. Such sloppiness was common in areas that were not readily accessible by the homeowner (knee walls, attics, etc.).

Figure D-17: Poorly Installed Fiberglass Attic Wall Insulation

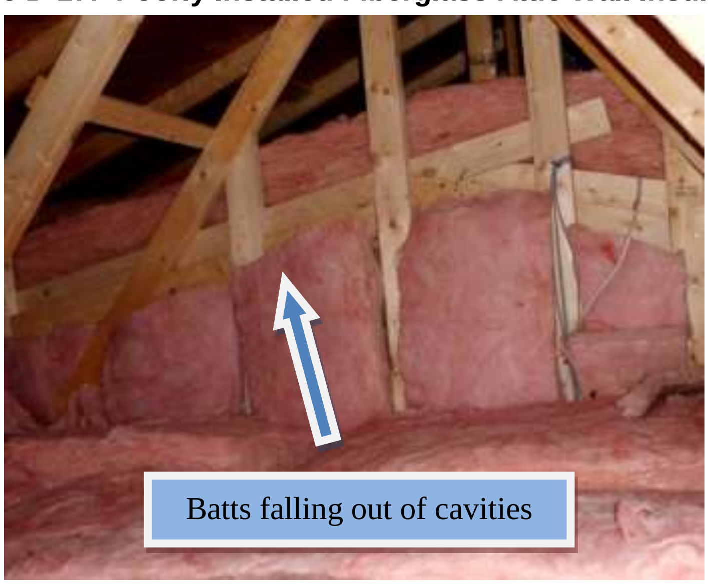
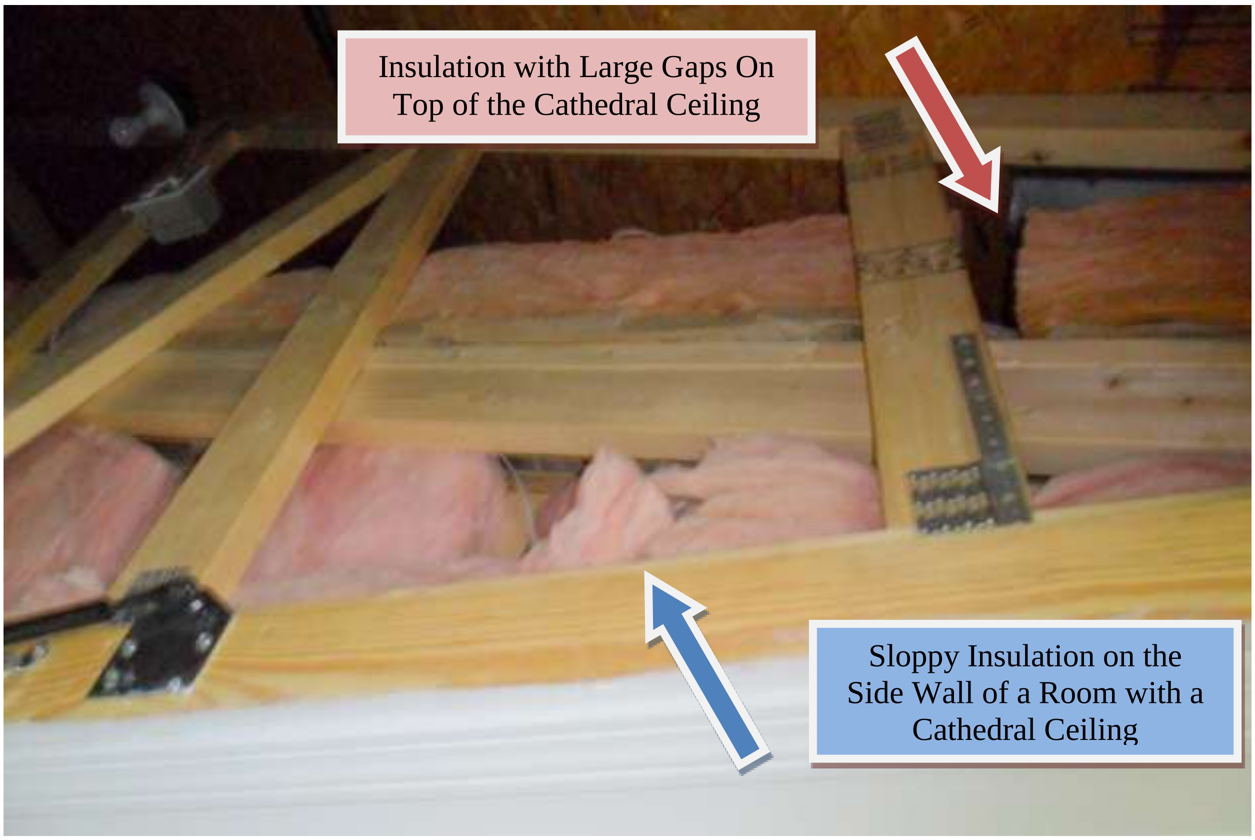


Figure D-18 shows a huge energy oversight by a builder. The photo looks up through an open attic hatch into the attic at the framing of a room with a cathedral ceiling. The poorly installed fiberglass batts in the middle of the photo were intended to insulate the wall rising above the flat ceiling level, but were doing almost nothing. The batts visible at the top of the photo were haphazardly placed on top of that cathedral ceiling area, with large gaps between the batts.

The builder also installed a built-in storage cabinet (not visible in the photo) that had not been fully sheetrocked on the backside, meaning that air could freely travel between the conditioned space and the attic through the back of the cabinet. During the blower door test, so much air blew in through this opening that the cabinet doors would not remain closed.

Figure D-18: Poorly Installed Ceiling and Attic Wall Insulation



Windows, Doors, and Basement Air Sealing

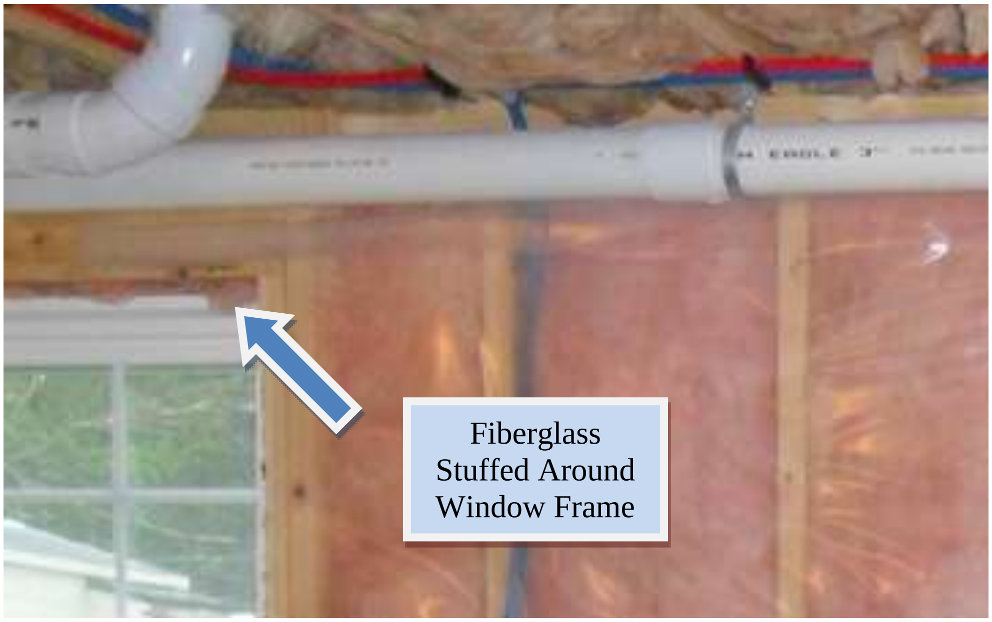
Homes with unfinished basements allowed auditors to see instances where builders had not properly air sealed around windows and doors.

Figure D-19 shows an unconditioned basement with no door to its bulkhead. The bulkhead hatch had large gaps around it, allowing air infiltration into the basement. Light is visible through a gap around the bulkhead hatch. Builders commonly failed to install a door in the foundation wall separating the basement from the bulkhead door. Installing a weather-stripped door in this foundation wall would have greatly reduced air leakage in the basement, where mechanical equipment was located.

Figure D-19: Basement Missing Door to Bulkhead Hatch

Figure D-20 shows an example of a common source of basement air leakage – window and door frames where gaps around the rough opening were filled only with bits of fiberglass batts, rather than spray foam, allowing air infiltration into the basement between the fibers of the fiberglass insulation.

Figure D-20: Fiberglass as Ineffective Air Sealing



Duct Quality and Location – Minimizing Ducts in Unconditioned Space

Homes that demonstrated the least duct leakage to the outside were typically those that minimized the amount of unconditioned space in the home, by bringing the attic and basement into the thermal envelope.

While Figure D-9 and Figure D-14 both demonstrate homes where the attic has been brought into the conditioned envelope, thereby improving the performance of their attic HVAC systems, Figure D-21 shows an air handler and ductwork on the floor of a vented attic space. The homeowner appeared to be bringing the attic into the conditioned space by insulating the roof rafters, but as designed, this uninsulated ductwork was in a vented attic, causing all duct leakage to be completely lost to the outside, which was particularly problematic in this case because the uninsulated portion of the ducts was unsealed.

Figure D-21: Uninsulated, Unsealed Ductwork in Vented Attic

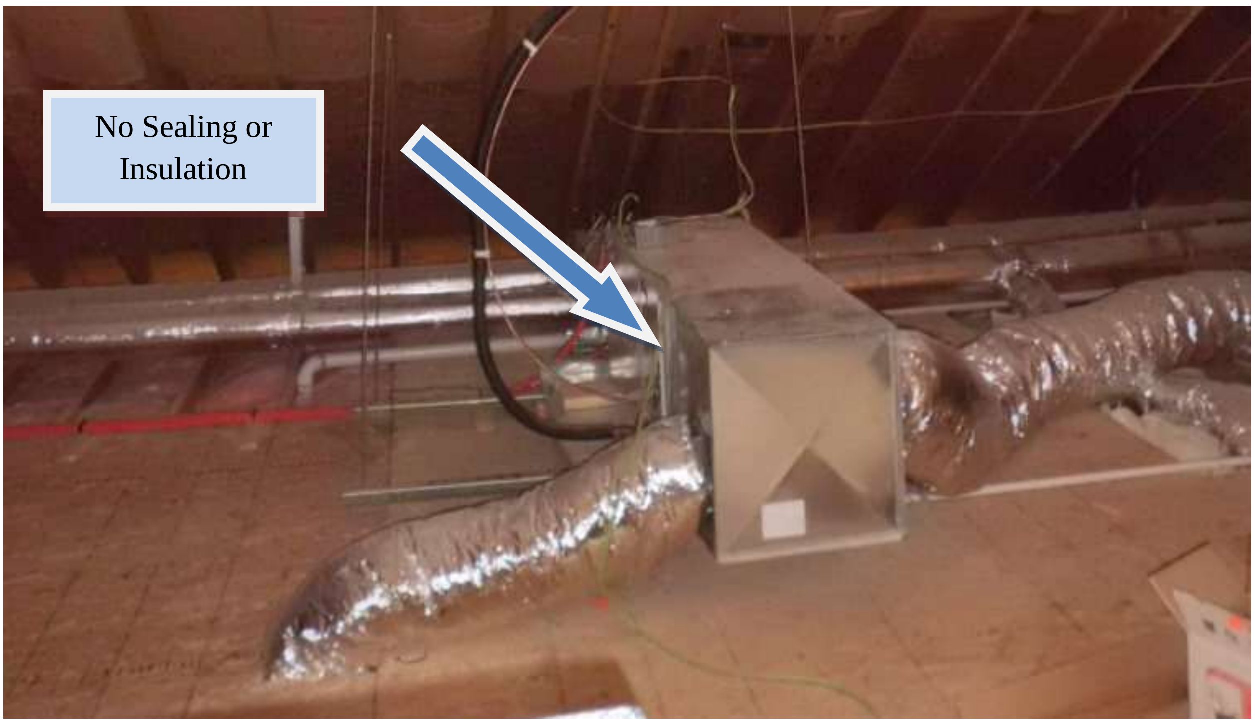


Figure D-22 shows another crawl space with spray foam installed as the frame floor insulation. While this closed cell foam helped to create a tight thermal barrier, the HVAC contractor had failed to seal the ductwork in the crawl space. One of several large unsealed panned joist duct returns is visible in the photo, allowing for free exchange of air between the home and the unconditioned crawl space. This was particularly problematic because the only door separating the crawl space from ambient conditions was a leaky bulkhead hatch door, meaning that outside air was freely being pulled into the leaky panned joist returns.

Figure D-22: Foam Frame Floor Insulation over Crawl Space with Leaky Panned Joists

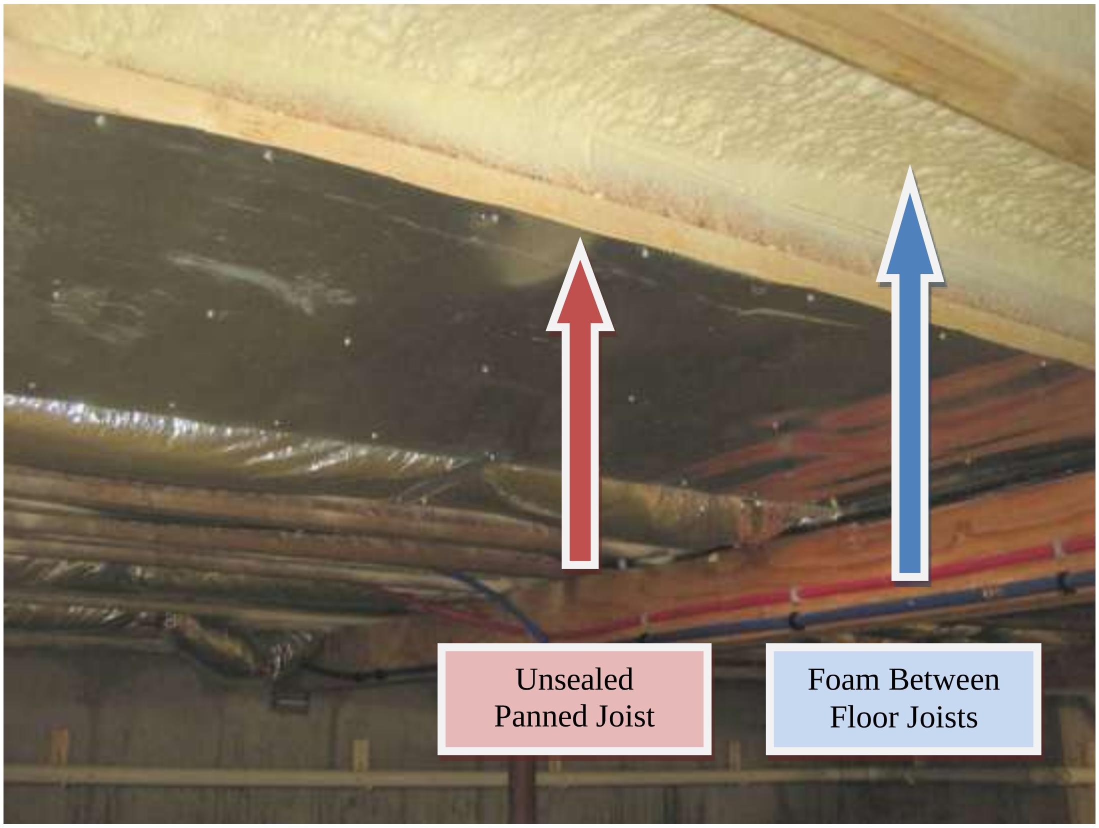


Figure D-23 shows where an HVAC contractor tried to install ductwork so as to bypass the main support beam running the length of the basement, running it over the beam and under the lower flange of a wood I-beam floor joist into the next floor joist bay. This uninsulated piece of flexible ductwork was wrapped tightly around these beams, constricting airflow in some areas.

This section was not kinked as badly as auditors occasionally saw in homes – insulated flexible ductwork in this circumstance often had its insulation largely crushed, diminishing its R-value. This photo also demonstrates the messy frame floor insulation commonly found around ductwork and piping. Flexible ducts were often twisted and crushed to fit in tight spaces like this.

Figure D-23: Kinked HVAC Ducts in Basement

Ventilation

Even extremely "tight" homes that auditors tested, those with very low air exchange rates, usually did not have automatic ventilation systems installed to provide fresh air. Builders installed standard bathroom fans, but rarely installed timed or automatic ventilation systems to bring fresh air into homes.

Mechanical Equipment

Figure D-24 shows the four, 14 SEER CAC condensing units of a large, 5,500 square foot home with about nine tons of cooling capacity. This home had significantly more cooling power than any other RI home visited, though the tonnage per square foot was average compared to the other RI homes with CAC. It only had 1.7 tons of cooling capacity per thousand square feet of CFA, whereas some smaller homes had proportionally much more (up to 2.9 tons per thousand square feet), even if their total consumption might be less.

Figure D-24: Large Home with Many HVAC Systems

Builders also often installed lower efficiency, non-condensing furnaces in attics, perhaps due to the risk of condensate freezing in unconditioned attics, especially if the furnaces need to be installed horizontally instead of vertically because of space limitations.[58] Bringing mechanical

[58] It would not be surprising to find that this is also a helpful cost-cutting measure by some builders, because they can install cheaper, lower efficiency systems in attics, where homeowners may be less likely to notice the presence of a less efficient system.

systems into the building envelope by insulating the attic and basement always greatly increased the performance of homes in the auditors' diagnostic tests, and would allow builders to install higher efficiency secondary furnaces in attics.

Figure D-25 shows the boiler of a home with a hydro-air HVAC system. The R-value of the insulation on the copper water lines was only 2.1, but it was installed significantly better than such foam insulation commonly is, as the insulation was mitered at the bends in the piping, minimizing the gaps common on such insulation. This sort of insulation is often missing entirely.

Figure D-25: Well-Installed Hot Water Pipe Insulation

Appendix E Data Collection Form

Baseline Study(s) Field Data Form-2011 | **Field Data Collection Form**

Site ID Number: | Name: | **General Information**

Fill out all data available from recruitment before going to site. Collect more detail during on-site audit.

Auditor 1		Date of Audit		Ambient Temp.	
					(Degrees F)
Auditor 2		Evaluation Region/County			
Street Address		City			
House Type		Attached/Detached		Stories	
	Area conditioned space (calc.)			Bedrooms	
	Volume conditioned space (calc.)				
Primary Heating Fuel		Total Heated Area			
		(from recruitment data)			
Basement type		Bsmt. Area		% Cond.	
		(approx. square feet)			
Completion Date		ENERGY STAR Home		Primary/Seasonal	
(month/year)					(Time-of-use if seasonal)
Location of Home		Builder Type			
		Own or Rent?			
				Winter	*Summer*
Type of Thermostat:		Preferred Temperature:			
Use Night Temp. Setback?		No of Occupants, Nights:			
Use Daytime Temp. Setback?		No of Occupants, Workdays:			
How many Fireplaces?		Indoor Temperature:		Zones:	
How many Portable Space Heaters?		Fireplace/ Stove Fuel:		T'stats:	
How many Stoves?		Space Heater Fuel:			
Wood fireplace gasketed?					
Do Blower Door?		Do Duct Blaster?		Do AC Performance Test?	

Insulation/Shell

Foundation Wall

For foundations, include ALL insulation (even walls in unconditioned space). Note where insulation was verified.

Wall Type	Int/Ext Insul	Location	Length	Height	Above Grade	Insul Type	R-Value

Notes:

Slab Floor

Note where insulation was verified.

Grade/Below Grade	Location of Slab Insulation	Total Perimeter	Exposed Perimeter	Above Grade Exposed Perimeter	Depth Below Grade	Area, SqFt	I-Type	R-Value

Notes:

Frame Floor

Note where insulation was verified.

Floor Description	Location	Area, SqFt	I Type	Cavity?	R-Val/Grade

Notes:

Rim/ Band Joists

Note where insulation was verified.

Joist Description	Location	Area, Linear F	I Type	R-Value	Thickness	Grade	Rim/Band

Notes:

Exterior Walls

Note where insulation was verified.

Wall Description	Location	Area	I Type	Cavity?	R-Val/Grade

Notes:

Windows	*Windows/glass doors and skylights. Note whether or not tested for Low-e*						O'hang/Di	
Type of Glass	SqFt	Frame	Location	U-value	SHGC	T Break	st.To Top	Orient
Notes:								

Ext. Doors							
Door Type	Material	Insulated	Storm?	Type of Glass	Dr SqFt	Gl SqFt	Orient.
Notes:							

Ceiling Insulation	*Note where insulation was verified.*					
Ceiling Construction	Flat/Cathedral	Area, SqFt	V Barrier	I Type	Cavity?	R-Val/Grade
Notes:						

Sky Lights								
Type of Glass	SqFt	Frame	Location	U-value	SHGC	T Break	Orient	Angle
Notes:								

Mass Wall

Note where insulation was verified.

Wall Type	Int/Ext Insul	Location	R-value

Notes:

Sunspace

*If sunroom need to treat like normal room, take all measurements, area, R-value, etc.

Surface Type	Location	Area	I Type	Cavity?	R-Val/ Grade	Orient.	Glass Frame Type

Notes:

Mechanicals

Heating Equipment

Manufacturer	Model	Type	Age	Fuel	Location	Cap. Out	Efficiency

For Forced Air System, How is Fan Controlled?	
R-value for hydronic piping insulation:	

Notes:

Furnace Motors

*We need to record any information on ECM motors. To be safe please record make and model of all furnace r

Manufacturer	Model	Type

Notes:

Water Heating

Manufacturer	Model	Type	Age	Fuel	Location	Gallons	Energy Factor

R-value for water heater wrap:	

Notes:

Cooling Equipment

Manufacturer	Model	Type	Age	Evap. Location	Tons	Efficiency
Notes:						

Duct Insulation

		For Insulation Only			Duct	Duct	Duct
Supply/Return	Location*	Type	Quality	R-Value	Type	Sealing	Leakage
Notes:							

* If ductwork is all within the conditioned space, no duct blaster test is required.

# of return grills

Test Results

Blower door and Duct blaster

Repeat tests as needed to ensure precision.

Blower Door Test 1 (at 50 Pa)	
Blower door type	Type 3
Ambient Temperature	
Fan Pressure (Pa)	
House Pressure (Pa)	
Rings/Holes	
CFM Leakage	

Duct Blaster Test 1 (at 25 Pa)	Total Leak Test	Out. Leak Test	System
D.B. Fan Pressure (Pa)			
Duct Pressure	25	25	
Rings			CFA Served
Blower door Fan (Pa)	0		
House Pressure (Pa)	0	25	
CFM Leakage			

Blower Door Test 2 (at 50 Pa)	
Blower door type	Type 3
Ambient Temperature	
Fan Pressure (Pa)	
House Pressure (Pa)	
Rings/Holes	
CFM Leakage	

Duct Blaster Test 2 (at 25 Pa)	Total Leak Test	Out. Leak Test	System
D.B. Fan Pressure (Pa)			
Duct Pressure	25	25	
Rings			CFA Served
Blower door Fan (Pa)	0		
House Pressure (Pa)	0	25	
CFM Leakage			

Blower Door Test 3 (at 50 Pa)	
Blower door type	Type 3
Ambient Temperature	
Fan Pressure (Pa)	
House Pressure (Pa)	
Rings/Holes	
CFM Leakage	

Duct Blaster Test 3 (at 25 Pa)	Total Leak Test	Out. Leak Test	System
D.B. Fan Pressure (Pa)			
Duct Pressure	25	25	
Rings			CFA Served
Blower door Fan (Pa)	0		
House Pressure (Pa)	0	25	
CFM Leakage			

Visual House Leakage:

Visual Supply Duct Leakage:

Visual Return Duct Leakage:

Lighting

Room	No. of CFL Fixtures/Bulbs	No. of Incan. Fixtures/Bulbs	No of Fluor. Tube Fixtures/Bulbs	No of LED Fixtures/Bulbs	# of Ceiling Fans by Room

Appliances

Appliance	Mfg.	Model No		Type	CuFt/Fuel	Age	Condition	E-Star?
Primary Refrigerator:								
Second Refrigerator:								
Stand-alone Freezer:								
Clothes Washer:								
Clothes Dryer:								
Dishwasher:								
Range or Combination								
Stand-alone Oven								
TV Sets & Peripherals	Size	Type	Service Type	Peripherals	Size	Type	Service Type	Peripherals
1,2								
3,4								
5,6								
7,8								

No. of Printers/Type: ______ List other Peripherals: ______

No. of Computers: ______ Is there an in-home office? ______ Ofc. Area ______

Computer Monitors: ______ Is there a Swimming Pool? ______ Heated? ______

Smart Power Strips: ______ Does pool have a pump timer? ______ Pump HP ______

Is there a Hot Tub or Spa? Heated?

Computer No	Mon Size	Mon Type	Print Type	E Star?
1				
2				
3				
4				

Renewables

PV Array? Y____ N____	SqFt:		Total kW:	
Windmill? Y____ N____	Count:		Total kW:	

Miscellaneous/Code

Inspect whole house ventilation equipment for compliance with Code. Document type of system and note any deficiencies below. Include any bathroom fans.

Type of ventilation system:		Fan Loc.	Rated CFM	Required	Control
Notes:					
		Total	0	0	NA

ERV/HRV Manufacturer	ERV/HRV Model No.	Efficiency	Notes:

Inspect any combustion equipment for compliance with Code. This includes space and hot water heating equipment, fireplaces, wood and pellet stoves. Does not include cooking equipment (including charcoal or gas grilles) or clothes dryers. Note any deficiencies below.

Equipment Type	Fuel	Venting	Comply?	% of Heat	Comments, esp. for Non-Compliance

Notes:

HVAC/Hot Water/Central Air Piping Insulation

System	Insulation Type	R-value	Notes:

Miscellaneous Code		
Recessed Fixtures meet infiltration criteria?		
Dampers on all outdoor intake and exhaust openings?		
Certificate posted?		
Wood burning fireplace--gasketed doors and outdoor air supply?		
Heat Pump thermostats installed on heat pumps?		
Circulating service hot water systems have automatic or accessible manual controls?		
Pool heaters, covers, and automatic or accessible manual controls?		
Air Sealing of opening and penetrations? (fenestration, window/door openings, utility penetrations)		
Air Sealing of envelope joints and seams? (dropped ceiling, kneewall, tub or shower, common wall, assemblies separating garage)		
Air Sealing of all other sources of penetration?		
Crawl space continuous vapor retarder installed with joints overlapped by 6 inches and sealed, and extending at least 6" up the stem wall.		
Exposed foundation insulation protection.		
Snow melt controls.		
Building cavities NOT used for supply ducts.		**Value**
Glazed fenestration air leakage available?		
Swinging door air leakage available?		
Fenestration and door labeled for air leakage?		
All installed insulation labeled or installed R-value provided.		
Floor insulation in substantial contact with the subfloor?		
Blown ceiling insulation marked off every 300 ft2?		

Document noteworthy and valuable information regarding the quality and performance of the home as it pertains to building science and energy usage.
Notes:

Appendix F On-site Homeowner Survey

2011 RI Baseline On-site Survey Questions

SITE ID:__________

OWNER NAME:____

HOME ADDRESS: ____

1. Name of Builder or Development: ______________________________________

2. Verify how home was purchased; verify with response recorded when home was recruited.
   ___ A. Purchased a lot from a builder, selected one of several house plans offered by the builder and selected from various available upgrade options.
   ___ B. Purchased a home that was under construction and selected from various available upgrade options.
   ___ C. Purchased land on my own and worked with an architect or designer to design the entire home.
   ___ D. Had a house plan and a lot and hired a contractor/builder to build the home.
   ___ E. Purchased a finished home.
   ___ F. I/we am/are the owner(s) and builder(s).
   ___ G. Other→ Please describe: ____

3. How comfortable would you say your home is?
   ___ A. Very comfortable
   ___ B. Somewhat comfortable
   ___ C. Somewhat uncomfortable
   ___ D. Very uncomfortable
   ___ E. Don't know

   Comments: ____

4. Do you have any complaints about your home?
   ___ A. Yes
   ___ B. No

   If yes, would you describe your complaints? ______________________________________
   ____

5. Did your builder or real estate agent talk to you about energy efficiency or the benefits of energy-efficient windows, heating and cooling equipment, insulation, etc.?
   ___ A. Yes
   ___ B. No
   ___ C. Do not remember

6. Did you ask your builder or the real estate agent marketing your home about energy efficiency?
   ___ A. Asked about energy efficiency
   ___ B. Did not ask about energy efficiency
   ___ C. Do not remember

7. How important was *getting a home that is energy efficient* in your decision to buy or build this particular home? Using a scale from 0 to 10, where 0 is "one of the least important features" and 10 is "one of the most important features." Please circle your response:

One of the least important features										One of the most important features
0	1	2	3	4	5	6	7	8	9	10

8. How strongly do you agree or disagree with the following statement: "All new homes are equally energy-efficient"?
   ___ A. Strongly agree
   ___ B. Agree
   ___ C. Neither agree or disagree
   ___ D. Disagree
   ___ E. Strongly disagree
   ___ F. Do not know

9. How energy efficient do you think your home is compared to other new homes?
   ___ A. Much more energy efficient
   ___ B. Somewhat more energy efficient
   ___ C. About as energy efficient as most other new homes
   ___ D. Somewhat less energy efficient
   ___ E. Much less energy efficient
   ___ F. Do not know

Why do you say that? ____

10. Did you have a custom home built or purchase your home before it was completed and had the opportunity to choose various options for your home?
    ___ A. Yes
    ___ B. No (SKIP TO QUESTION 19)

<u>For Questions 11 through 18 – Please indicate, as far as you know, who made the decision for each of the following energy efficiency-related components in your home?</u>

11. **Windows**
    ___ A. I Specified aspects of the windows to install (Check all that apply:)
        ___ 1. I specified the style (double hung, casement, awning, slider, frame material or color, panes dividers, etc.)
        ___ 2. I specified the number of panes of glass (single-, double- or triple-pane)
        ___ 3. I specified the Energy efficiency (U-value)
        ___ 4. I specified that they be ENERGY STAR windows
    ___ B. The builder chose the windows
    ___ C. I Selected the windows from options offered by the builder
    ___ D. Do not remember or do not know

12. **Heating System**
    ___ A. I Specified aspects of the heating system (Check all that apply:)
        ___ 1. Heating fuel (electric, natural gas, propane, oil, etc.)
        ___ 2. Type of heating system (furnace, boiler, heat pump, ground source heat pump, etc.)
        ___ 3. Energy efficient heating system
        ___ 4. ENERGY STAR-labeled heating system
    ___ B. Builder chose the heating system
    ___ C. I Selected the heating system from options offered by the builder
    ___ D. Do not remember or do not know

13. **Central Air Conditioning**
    ___ A. No Central Air Conditioning
    ___ B. I Specified aspects of the central air conditioning (Check all that apply:)
        ___ 1. Whether or not to install central air conditioning
        ___ 2. Type of system (standard central A/C system, air source heat pump, ductless mini-split system, combined heating and cooling system)
        ___ 3. Energy efficient system
        ___ 4. ENERGY STAR-labeled system
    ___ C. Builder chose
    ___ D. I Selected from options offered by the builder
    ___ E. Do not remember or do not know

14. **Water Heating**
    ___ A. I Specified aspects of the water heater (Check all that apply:)
        ___ 1. Fuel used to heat water
        ___ 2. Type of system (stand-alone tank, integrated tank with boiler, tankless, tankless combined with boiler heating system, point of use, etc.)
        ___ 3. Energy efficient system
        ___ 4. ENERGY STAR-labeled system
    ___ B. Builder chose
    ___ C. I Selected from options offered by the builder
    ___ D. Do not remember or do not know

15. **Kitchen Appliances**
    ___ A. I Specified aspects of appliances to install (Check all that apply:)
        ___ 1. Gas or electric
        ___ 2. Brand/manufacturer
        ___ 3. Color/style
        ___ 4. Energy efficient appliances
        ___ 5. ENERGY STAR-labeled appliances
    ___ B. Builder chose the appliances
    ___ C. I Selected the appliances from options offered by the builder
    ___ D. Do not remember or do not know

16. **Framing:** (2x4 or 2x6 wood framing; 16 or 24 inch-on-center wood framing: steel framing; SIPS (Structural Insulated Panels); ICF (Insulated Concrete Form) blocks; etc.)
    ___ A. I Specified the wall framing
    ___ B. Builder chose the wall framing
    ___ C. I Selected the wall framing from options offered by the builder
    ___ D. Do not remember or do not know

17. **Type and/or level of insulation**
    - ___ A. I Specified the type and/or level of insulation (Check all that apply:)
        - ___ 1. Type of insulation (fiberglass batts, blown-in cellulose, spray foam, rigid foam, etc.)
        - ___ 2. Level of insulation (R-value)
    - ___ B. Builder chose
    - ___ C. I Selected the insulation from options offered by the builder
    - ___ D. Do not remember or do not know

18. **Lighting Fixtures**
    - ___ A. I Specified aspects of the lighting fixtures (Check all that apply:)
        - ___ 1. I could choose any fixtures from any stores
        - ___ 2. I was given a budget allowance to use at a specific store or catalog
        - ___ 3. I wanted energy –efficient lighting fixtures
        - ___ 4. I wanted ENERGY STAR lighting fixtures
    - ___ B. Builder chose the lighting fixtures
    - ___ C. I Selected the lighting fixtures from options offered by the builder
    - ___ D. Do not remember or do not know

19. In the following table, please put an X in the column that best describes how energy efficient you believe each of the listed components in your home to be. Please put an X in the "ENERGY STAR® Labeled" column if you know it is an ENERGY STAR-labeled product.

Home Component	Very Energy Efficient	Average	Not Energy Efficient	Do Not Know		ENERGY STAR Labeled
Windows						
Heating System						
Central Air Conditioning						
Water Heater						
Refrigerator						
Dishwasher						
Clothes Washer						
Type of insulation						
Level of insulation						
Lighting fixtures						

20. Have you ever seen or heard of a newly constructed home being referred to as an ENERGY STAR home?
    ___ A. Yes
    ___ B. No (SKIP TO QUESTION 23)
    ___ C. Do not know (SKIP TO QUESTION 23)

21. Did any builders or real estate agents you talked to while shopping for a home bring up the subject of ENERGY STAR homes?
    ___ A. Yes
    ___ B. No
    ___ C. Do not remember

22. Did you ask any builders or real estate agents about ENERGY STAR Homes when you were making your plans for building or buying a home?
    ___ A. Yes
    ___ B. No
    ___ C. Do not remember

23. Are you a first-time home buyer, or did you already own a home before you bought this one?
    ___ A. First-time home buyer
    ___ B. Already owned home
    ___ C. Don't know or prefer not to answer

24. How long do you expect to stay in your new home?
    ___ A. One year or less
    ___ B. Two to three years
    ___ C. Four to five years
    ___ D. Six to ten years
    ___ E. More than ten years
    ___ F. Indefinitely/the rest of my life
    ___ G. Don't know

25. What is the highest level of education that you have completed?
    ___ A. Less than high school
    ___ B. High school graduate
    ___ C. Technical or trade school graduate
    ___ D. Some college
    ___ E. College graduate
    ___ F. Some graduate school
    ___ G. Graduate degree
    ___ H. Prefer not to answer

26. What is your age?
    - ___ A. 18 to 24
    - ___ B. 25 to 34
    - ___ C. 35 to 44
    - ___ D. 45 to 54
    - ___ E. 55 to 64
    - ___ F. 65 or over
    - ___ G. Prefer not to answer

27. What category best describes your total household income in 2010, before taxes?
    - ___ A. Less than $35,000
    - ___ B. $35,000 to $49,999
    - ___ C. $50,000 to $74,999
    - ___ D. $75,000 to $99,999
    - ___ E. $100,000 to $149,999
    - ___ F. $150,000 or more
    - ___ G. Prefer not to answer

THANK YOU!