# Connecticut 2011 Baseline Study of Single-Family Residential New Construction

## *Final Report*

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**Submitted by:**

**NMR Group, Inc.**

**KEMA, Inc.**

**Cadmus**

**Dorothy Conant**

50-2 Howard Street, Somerville, MA 02144
Phone: (617) 284-6230 Fax: (617) 284-6239
www.nmrgroupinc.com

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# Executive Summary

This study was conducted to estimate as-built energy use characteristics for homes that were not part of the Energy Efficiency Fund New Construction Program (RNC) as a baseline for the RNC Program. Resulting information will be applied to estimation of the net effects of the RNC Program on efficiency improvements. Additionally, these results are used to establish preliminary estimates of User Defined Reference Home (UDRH) inputs to be used as baseline characteristics against which construction within the RNC Program can be compared. Findings are based on the results of on-site inspections, including Home Energy Rating System (HERS) ratings, of 69 homes that were not part of the RNC program, were completed from November 2009 through July 2011, and whose owners agreed to have their home inspected. The statistical sample of 69 inspected homes are a mix of custom and spec single-family homes located in 61 different cities and towns across Connecticut, with the percentage of inspected homes in a county matched to the percentage of statewide single-family building permits issued in that county.

Throughout this report 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.

## *Purpose and Cautions*

The purpose of this study is to report on what baseline construction practices are employed in new homes being built <u>outside</u> Connecticut's Residential New Construction (RNC) Program. This study does not attempt to assess whether or not individual homes complied with current building codes or assess code enforcement. In Connecticut, as in many other places, both prescriptive (as provided in 2006 and 2009 International Energy Conservation Code) and performance methods are used to determine code compliance. The authors of this study could not and have no reason to attempt to replicate code officials' inspection results. All inspected homes are recently completed occupied homes inspected by a building official and issued a certificate of occupancy. Therefore, there is every reason to consider each of the 69 homes inspected for this study to have met the requirements of the applicable building energy code. The authors of this study do not and could not replicate what code officials would assess.

Indeed, individual home code compliance is immaterial to this study. For purposes of this study, which is to estimate the energy features of homes that are being built across Connecticut when the builder does not participate in the RNC Program, inspected homes are a statistically-based sample used to estimate construction characteristics *and not code compliance* across the state as a whole. Additionally, these results are used to establish preliminary estimates of User Defined Reference Home (UDRH) inputs to be used as baseline characteristics against which construction within the RNC Program can be compared.

Preliminary estimated UDRH insulation inputs are based on the average of reported insulation levels and the U-values[1] calculated by the REM/Rate™ software used to produce HERS ratings. In the body of the report, information is also provided on the percentage of homes that exceed or fall short of specific insulation levels. Information on the percentage of homes with low insulation levels in different areas (e.g., walls, ceilings, and floors) helps identify those areas in new homes where there may be the most opportunity for increasing insulation levels and energy savings. The specific insulation levels to which homes are compared are the insulation levels required if a builder chose to comply with IECC prescriptive requirements—these are insulation levels that are widely accepted as the basis of comparison in discussions of how 2006 IECC requirements compare to 2009 IECC requirements. Looking at 2009 as well as 2006 IECC requirements is relevant because the 2009 IECC became effective in Connecticut for all building permits filed on or after October 7, 2011, which means a high percentage of homes completed in 2012 will be permitted under 2009 IECC. A word of caution—it is important to remember that a home that has less insulation in some areas than would be required if it was built to comply with IECC prescriptive path requirements is **not** an indication that the home failed to comply with code requirements.

## *Comparisons with 2006 IECC Prescriptive Insulation Levels*

As described above, a home with insulation levels that are lower than would be required compared to 2006 IECC prescriptive requirements suggests the home was built to meet the requirements of a performance compliance path that allows trade-offs. However, since in most inspected homes (66 out of 69) the insulation level in at least one area of the home is lower than would be required under the 2006 IECC prescriptive compliance path, it is interesting to see how many homes have lower than prescriptive insulation levels in various areas. The 2006 IECC prescriptive compliance path insulation levels are listed below:

- Wood framed wall insulation of R-19 or R-13 cavity plus R-5 insulated sheathing
- 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)
- Floors over unconditioned space of R-30 or framing cavity filled
- Ducts in unconditioned space insulated to R-8

Table ES 1shows that 28% of homes (19 homes) have less duct, ceiling and floor insulation than required for homes built to meet 2006 IECC prescriptive path requirements; 19% (13 homes) have less duct and ceiling insulation than required; and 10% (7 homes) have less ceiling insulation than required. In only three homes (two custom homes and one spec home) are all insulation levels at least as high as 2006 IECC prescriptive path requirements. In two homes (one

[1] UDRH inputs for walls, floors and ceilings are U-values, which 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

custom home and one spec home) all insulation levels are lower than 2006 IECC prescriptive path requirements. (See Appendix A Comparison to 2006 IECC Prescriptive Insulation Levels by Site for a list, by home, of how insulation levels in individual inspected homes compare to 2006 IECC prescriptive path required insulation levels.)

**Table ES 1: By Home Comparison to 2006 IECC Prescriptive Insulation Levels**

| Insulation Levels Lower than 2006 IECC Prescriptive Path Requirements[2] | All Homes (n=69) | |
|---|---|---|
| | Number of Homes* | Percent of Homes |
| Duct, Ceiling & Floor | 19 | 28% |
| Duct & Ceiling | 13 | 19% |
| Ceiling | 7 | 10% |
| Duct | 6 | 9% |
| Duct & Floor | 6 | 9% |
| Ceiling & Floor | 5 | 7% |
| Floor | 3 | 4% |
| Foundation Wall & Ceiling | 1 | 1% |
| Foundation Wall, Duct & Floor | 1 | 1% |
| Wood Framed Wall & Ceiling | 1 | 1% |
| Wood Framed Wall & Floor | 1 | 1% |
| Wood Framed Wall, Duct, Ceiling & Floor | 1 | 1% |
| Wood Framed Wall, Duct & Ceiling | 1 | 1% |
| Wood Framed Wall, Foundation Wall, Duct & Floor | 1 | 1% |
| All Insulation Levels at Least as High as Prescriptive Path Requirements: | 3 | 4% |

*Each home is counted only once.

## Building Shell Insulation Findings

### Conditioned/Ambient Wall Insulation

The average R-value of conditioned/ambient wall insulation in inspected homes is R-19 and the average U-value is 0.068; the average U-value is lower (more energy efficient) than the current UDRH input of U-0.070. Most homes—64 out of 69 or 93% of homes—have R-19 or higher insulation in wood framed conditioned/ambient walls; R-19 is the 2006 IECC prescriptive level for wood framed wall insulation.[3] Only three homes have R-20 or higher conditioned/ambient wall insulation; R-20 or R-13 cavity insulation plus R-5 insulated sheathing, is the 2009 IECC prescriptive level for wood framed wall insulation. Fiberglass batt insulation is clearly dominant.[4] Auditors report that conditioned/ambient walls in 97% of inspected homes are insulated with fiberglass batts. (See Section 7.1.1 Conditioned/Ambient Walls for more information.)

[2] Homes assessed under a performance approach would not have to meet these requirements.
[3] The default assumptions for the level of insulation when it was not observable were R-19 for 2x6 stud walls and R-11 for 2x4 stud walls; these are common insulation values for these size walls.
[4] The default assumption for the type of insulation if it was not visible was fiberglass batts if that was the type of insulation visible in other areas of the home.

### Foundation Wall Insulation

The average R-value of insulation in foundation walls that bound conditioned space is R-17. All but one of the inspected homes that would be required to insulate foundation walls under the 2006 IECC prescriptive path—17 out of 18 homes or 94%—have at least R-10 continuous or R-13 cavity insulation, which is the 2006 IECC prescriptive path requirement.[5] In the one home that does not meet the prescriptive foundation wall insulation level, neither the foundation walls nor the frame floor between the basement and first floor is insulated. Foundation walls in all but one of the 17 inspected homes with insulated foundation walls are insulated with fiberglass batts. (See Section 7.6 Foundation Wall Insulation for more information.)

### Ceiling Insulation

The average R-value of flat ceiling insulation in inspected homes is R-34 and the average U-value is 0.0441; the average U-value is higher (less energy efficient) than the current UDRH input of U-0.0384. The average R-value of cathedral ceiling insulation in inspected homes is R-32 and the average U-value is 0.0417; the average U-value is lower (more energy efficient) than the current UDRH input of U-0.0534. Overall, fewer than one-third of inspected homes with ceiling insulation information (20 out of 68 homes or 29%) have R-38 or more insulation in flat ceiling areas and not more than 500 square feet of cathedral ceiling area with less than R-38, but at least R-30, insulation—the required 2006 and 2009 IECC prescriptive path ceiling insulation levels. (See Section 7.2 Ceiling Insulation for more information.)

### Floor Insulation

The average R-value of insulation in floors over unconditioned basements in inspected homes is R-20 and the average U-value is 0.074; the average U-value is higher (less energy efficient) than the current UDRH input of U-0.070. Fewer than one-half of the homes with floors over unconditioned space (26 out of 64[6] homes or 41%) have R-30 or higher insulation or the framing cavity filled (minimum R-19), the 2006 and 2009 IECC prescriptive floor insulation standards. (See Section 7.3 Floor Insulation for more information and a discussion of floors over garages, outside air and crawlspaces.)

[5] The prescriptive compliance path requires that foundation walls in homes with conditioned basement space, where the conditioned space is bounded by a foundation wall, be insulated; foundation walls in homes with unconditioned basements or walls in conditioned basements where the conditioned space is not bounded by a foundation wall are not required to be insulated.
[6] Five inspected homes did not have any floor area over unconditioned space.

### *Combined Ceiling and Floor Insulation Levels*

Table ES 2 shows that all ceiling and floor areas meet 2006 and 2009 IECC prescriptive insulation standards in only 9 (13%) of inspected homes; 4 or 18% of custom and 5 or 11% of spec homes. No ceiling or floor areas meet prescriptive levels in 25 or 36% of inspected homes; 6 or 27% of custom and 19 or 40% of spec homes. Some ceiling or floor areas do not meet prescriptive levels in 35 or 51% of homes; 12 or 55% of custom and 23 or 49% of spec homes.

**Table ES 2: Combined Ceiling and Floor Insulation Levels**

| Combined Ceiling and Floor Insulation Levels Compared to 2006 and 2009 IECC Prescriptive Requirements | All Homes (n=69) | | Custom Homes (n=22) | | Spec Homes (n=47) | |
|---|---|---|---|---|---|---|
| | Number of Homes | Percent of Homes | Number of Homes | Percent of Homes | Number of Homes | Percent of Homes |
| All Ceilings and Floor Areas Meet Prescriptive Levels | 9 | 13% | 4 | 18% | 5 | 11% |
| No Ceiling or Floor Areas Meet Prescriptive Levels | 25 | 36% | 6 | 27% | 19 | 40% |
| Some Ceiling or Floor Areas do not Meet Prescriptive Levels | 35 | 51% | 12 | 55% | 23 | 49% |

## *Duct Insulation and Leakage*

### *Duct Insulation*

Under 2006 IECC it is a mandatory requirement that ducts located in unconditioned space have a minimum of R-8 insulation. Most (62 of 69) inspected homes have at least some ducts in unconditioned space and fewer than one-fourth of these homes (14 out of 62 homes or 23%) have all ducts insulated to R-8; uninsulated ducts in unconditioned space were observed in five homes. Under 2009 IECC, duct insulation requirements are relaxed. Under 2009 IECC it is mandatory that ducts located in unconditioned space have a minimum of R-6 insulation. The 2009 IECC prescriptive path requires that supply ducts located in attics be insulated to R-8, while all other ducts located in unconditioned space be insulated to R-6. Thirty-six out of 62 or 58% of homes meet the 2009 IECC standard, having at least R-8 supply attic duct insulation and all other ducts located in unconditioned space insulated to at least R-6. (See Section 9, Ducts, for more information.)

### *Duct Leakage*

Auditors were able to conduct duct leakage tests at 61 of the 64 inspected homes with ducts. Average duct leakage is 17.7 CFM25[7] per 100 sq. ft. of conditioned floor area, which is virtually the same as the current UDRH input of 17.3. The 2006 IECC does not have a duct leakage requirement, but the 2009 IECC has a mandatory requirement of 8 or less CFM25 per 100 sq. ft.

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

of conditioned floor area for ducts tested post construction. Only six of the inspected homes tested meet the 2009 IECC requirement.

Duct leakage in individual homes ranges from 5.0 to 46.4 CFM25 per 100 sq. ft. of conditioned floor area; the overall average is 17.7, the average for custom homes is 17.1 and the average for spec homes is l8.0. Putting duct leakage results into perspective, 17.7 CFM25 per 100 sq. ft. of conditioned floor area is:

- More than double 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. No inspected homes had duct leakage of 4 or less CFM25 per 100 sq. ft. of conditioned floor area.

(See Section 9.5 Duct Leakage for more information.)

## *Air Infiltration*

Auditors conducted blower door tests at all 69 inspected homes. Average air infiltration in inspected homes is 5.8 air changes per hour measured at 50 Pascals (ACH50). There are no specific air infiltration measurement requirements under either the 2006 or 2009 IECC prescriptive paths. However, both 2006 and 2009 IECC require determining adequacy of air sealing via visual inspection. Under 2009 IECC, air sealing can be considered compliant via blower door testing if ACH50 is 7 or lower. Overall, 54 of the 69 inspected homes (78%) have 7 or lower ACH50; 15 of 22 custom homes (68%) and 39 of 47 spec homes (83%).

The ENERGY STAR Version 3 performance path requires air infiltration to be 4 ACH50 or lower; 13 of 69 homes (19%) have 4 or lower ACH50; 6 of 22 of custom homes (27%) and 7 of 47 spec homes (15%). (See Section 10 Air Infiltration for more information.)

## *Mechanical Equipment—Heating, Cooling and Water Heating*

There are no prescriptive requirements for heating, cooling or water heating system efficiencies under either 2006 or 2009 IECC other than they need to meet federal minimum efficiency standards. However, average equipment efficiencies are UDRH inputs and affect estimated savings. For example, if a home completed through the RNC Program had a natural gas furnace with an Annual Fuel Utilization Efficiency (AFUE) of 95, and in inspected non-participant homes the average natural gas furnace AFUE was 92, then the home that participated in the RNC Program would be credited with the savings attributable to having a higher efficiency heating system.

### *Heating Systems*

Most inspected homes have propane (42%) or natural gas (36%) heating systems, most have furnaces (70%), and most heating systems are installed in unconditioned basements (74%).

Overall, homes have very energy-efficient heating systems; 85% of fuel-fired heating systems are ENERGY STAR qualified, and for all but the three oil furnaces observed in inspected homes, the average and median AFUEs meet ENERGY STAR-qualification criteria in effect when the systems were installed.[8] (See Section 8.1 Heating Systems for more information.)

### Cooling Systems

Most inspected homes (86%) have central air conditioning. Auditors report a total of 79 air conditioning units in 59 homes. Most (74%) of 76 central air conditioning units with Seasonal Energy Efficiency Ratio (SEER) information are SEER 13.0 units; the average SEER is 13.4, which is slightly higher than the current UDRH input of 13.0 SEER. One home has a geothermal heat pump that met the criteria for ENERGY STAR qualification when it was installed in 2010. Overall, there are 14 split system central air conditioners in 12 homes that, based on the outdoor unit model, may be ENERGY STAR-qualified. (See Section 8.2 Cooling for more information.)

### Cooling System Performance

In-field measurements were performed on 41 central cooling units to calculate the actual cooling capacities and efficiencies of a sample of residential central air conditioning (CAC) systems. Comparing average rated capacity and efficiency to average calculated capacity and efficiency shows average calculated capacity is 15.4% less than rated and the average calculated seasonal energy efficiency ratio (SEER) is 8.9% lower than rated. (See Section 8.3 HVAC Performance Testing for more information.)

### HVAC Equipment Oversized

REM/Rate software was used to calculate the design cooling and/or heating loads for all 69 inspected homes and the design loads were compared to what was installed in the homes. Results show that the average installed cooling system rated capacity is 1.99 times the properly sized system capacity, and that cooling systems are oversized in 97% or 57 of the 59 inspected homes with central cooling. On average, heating systems are also oversized. Average installed heating system capacity is 1.66 times the properly sized heating capacity; however, surprisingly, 11 of the 68 homes with heating system data (16%) have undersized heating systems. (See Section 8.4 Heating and Cooling Equipment Sizing—Manual J for more information.)

### Water Heating

More than one-half of inspected homes (58% or 40 homes) have conventional storage tank water heaters, 15 homes (22%) have instantaneous water heaters, 9 homes (13%) have indirect storage tank systems that use the home's boiler heating system to heat water, and 5 homes have boiler heating systems with tankless coil water heating. Water heater Energy Factors vary widely depending on the type of system. Of the water heaters eligible for ENERGY STAR qualification

[8] Updated ENERGY STAR criteria for natural gas and propane furnaces in Northern states, including Connecticut, went into effect February 1, 2012. The ENERGY STAR criteria for natural gas and propane furnaces increased from AFUE 90 to AFUE 95.

(instantaneous and high-efficiency natural gas and propane conventional storage tank water heaters), 33 of 41 water heaters (80%) most likely met ENERGY STAR criteria when they were installed.[9] (See Section 8.5 Water Heating for more information.)

## Mechanical Ventilation

Only five of the audited homes have mechanical ventilation that meets the REM/Rate definition:[10] one home has a heat recovery ventilation system (HRV), one home has a whole house attic fan that is thermostatically controlled, one home has a bathroom fan on a timer, and the other two homes have integrated bathroom fans.[11] All but one of the inspected homes has at least one bathroom exhaust fan. (See Section 8.6 Mechanical Ventilation for more information.)

## Appliances

Auditors collected detailed information on refrigerators, dishwashers, and clothes washers. There is a high penetration of ENERGY STAR-qualified appliances: 49 out of 69 (71%) of primary refrigerators, 8 out of 19 (42%) of secondary refrigerators, 57 out of 63 (90%) of dishwashers, and 43 out of 64 (67%) of clothes washers. (See Section 12 Appliances for more information.)

## Lighting

Looking at the total number of hard-wired (permanently installed) fixtures counted in visited homes, an average of only 10% of fixtures per home contain energy-efficient bulbs. The 2006 IECC does not have a lighting requirement, but 2009 IECC requires that 50% of the lighting "lamps" (bulbs, tubes, etc.) in a building must be high efficiency for homes complying under a prescriptive approach. Only three (4%) of the homes visited have 50% or more of their lighting fixtures fitted with bulbs classified as energy efficient and meet the prescriptive lighting requirement for 2009 IECC homes complying under a prescriptive approach.[12] (See Section 11 Lighting for more information.)

[9] ENERGY STAR criteria for high efficiency natural gas and propane conventional storage tank water heaters increased from 0.62 Energy Factor to 0.67 Energy Factor for units manufactured after August 31, 2010.

[10] 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).”

[11] Integrated bathroom fans have a humidity sensor that automatically powers the fan.

[12] This analysis assumes that the proportion of energy-efficient fixtures would be equal to the proportion of energy efficient bulbs or lamps installed in the home.

## *Custom and Spec Home Differences*

HERS Indices, because they address the house as a system, provide an overall indication of a home's energy efficiency. Table ES 3 shows the average HERS index is lower (more energy efficient) for custom homes (HERS 77) than spec homes (HERS 84); this difference is statistically significant at the 90% confidence level.

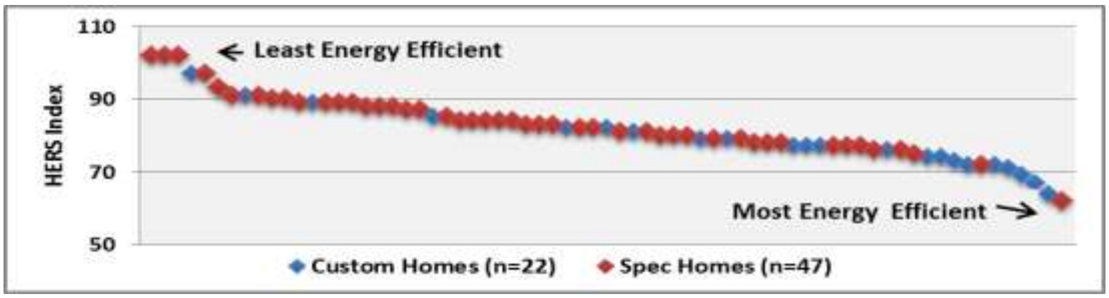
**Table ES 3: Comparison of Custom and Spec Home HERS Indices**

| HERS Index | All Homes (n=69) | Custom Homes (n=22) | Spec Homes (n=47) |
|---|---|---|---|
| Minimum | 62 | 64 | 62 |
| Maximum | 102 | 97 | 102 |
| Average | 82 | 77* | 84* |

*Significantly different at the 90% confidence level.

Figure ES 1 graphs HERS indices by home. HERS indices range from a high (least energy-efficient) of 102 to a low (most energy efficient) of 62.

**Figure ES 1: HERS Indices by Home**




Comparing individual building characteristics—insulation R-values, glazing percentages, heating and cooling system efficiencies and capacity sizing ratios, water heater efficiencies, duct insulation and leakage, air infiltration, presence of energy-efficient lighting, penetration of ENERGY STAR-qualified appliances—in custom and spec homes shows differences are generally minimal. (Appendix B Comparison of Custom and Spec Homes)

Differences that are statistically significant at the 90% confidence level include:

- Custom homes have significantly higher SEER cooling systems.
- Custom homes have significantly higher duct insulation R-values.
- Custom homes are significantly more likely to have an ENERGY STAR dishwasher.

## *User Defined Reference Home (UDRH) Inputs*

The results of this study will be used to update current Connecticut UDRH inputs. REM/Rate software is used to estimate the difference in energy use between a home completed through the RNC Program and an appropriate reference home (UDRH)—a comparable home with the energy efficiency characteristics of inspected non-participant homes. Table ES 4 compares study findings for all inspected homes to selected current UDRH inputs. (See Section 3 Preliminary

UDRH Input Estimates for information on all UDRH inputs.) Table cells highlighted in grey identify current UDRH inputs that study findings suggest may overestimate the energy efficiency of current building practices or equipment in homes being built outside the Connecticut RNC Program.

UDRH inputs for walls, floors and ceilings are U-values, which 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. Table ES 4 shows that efficiency levels in inspected homes are higher than current UDRH inputs for conditioned/ambient walls, cathedral ceilings, air infiltration, heating systems, cooling systems, and propane, natural gas, and oil conventional (stand-alone) tank water heaters. Efficiency levels in inspected homes are lower than current UDRH inputs for flat ceilings, floors and duct leakage.

**Table ES 4: Study Findings Compared with 2011 UDRH Inputs**

| UDRH Input | 2011 UDRH Input | Study Homes | Study Homes More or Less Efficient than 2011 UDRH |
|---|---|---|---|
| **Building Information** | | | |
| Wall Cavity Insulation (Uo or U-value) | 0.070 | 0.068 | Study Homes More Efficient |
| Flat Ceiling Insulation (Uo or U-value) | 0.0384 | 0.0441 | Study Homes Less Efficient |
| Cathedral Ceiling Insulation (Uo or U-value) | 0.0534 | 0.0417 | Study Homes More Efficient |
| Floor Insulation Cond/Basement (Uo or U-value) | 0.070 | 0.074 | Study Homes Less Efficient |
| Average Air Infiltration (ACHnat) | 0.32 | 0.29* | Study Homes More Efficient |
| Air Infiltration (ACH50) | n/a | 5.8 | n/a |
| **System Information** | | | |
| Oil-Fired Heating Systems (AFUE) | 83.3 | 84.5 | Study Homes More Efficient |
| Natural Gas Heating Systems (AFUE) | 90.0 | 92.4 | Study Homes More Efficient |
| Propane Heating Systems (AFUE) | 87.1 | 92.1 | Study Homes More Efficient |
| Cooling System Efficiency (SEER) | 13.0 | 13.4 | Study Homes More Efficient |
| Propane Conventional Water Heater (Energy Factor) | 0.56 | 0.60 | Study Homes More Efficient |
| Natural Gas Conventional Water Heater(EF) | 0.58 | 0.62 | Study Homes More Efficient |
| Oil Conventional Water Heater (Energy Factor) | 0.61 | 0.63 | Study Homes More Efficient |
| Electric Conventional Water Heater (Energy Factor) | 0.90 | 0.90 | Study Homes and UDRH the Same |
| Duct Leakage (CFM25/100 Sq. Ft.) | 17.3 | 17.7 | Study Homes Less Efficient |
| Duct Insulation R-value (supply) | 4.6 | 7.4 (attic7.7) | Study Homes More Efficient |
| Duct Insulation R-value (return) | 4.6 | 6.8 (attic7.4) | Study Homes More Efficient |

*Average ACHnat air infiltration is the average of the heating season and cooling season ACHnat values calculated in the REM/Rate files.

See Section 3 Preliminary UDRH Input Estimates for detailed information showing the data used to develop the estimated UDRH inputs. Section 4 Comparison to Previous Baseline Study Findings compares 2011 Baseline Study findings to previous baseline study findings and UDRH inputs as well as current UDRH inputs.

## *Homeowner Survey*

Homeowners were asked to complete a short survey during the on-site inspections. Questions addressed participation in utility-sponsored energy efficiency programs, how homes were purchased, if energy efficiency was discussed between the homeowner and the real estate agent or builder, how important energy efficiency was in the decision to purchase the home, and homeowners' perception of the energy efficiency of their homes. The survey also asked homeowners to indicate who specified various components in the home. (See Appendix H On-site Homeowner Survey Instrument.)

The results of the homeowner survey suggest many home buyers may start out wanting an energy-efficient home, but do not know what to look for or ask about to ensure they get an energy-efficient home. It isn't until after they are living in their new home that they find out it may not be as energy efficient as they expected or wanted. Fewer than one-half (40%) of homeowners say their builder or sales agent talked to them about energy efficiency or the benefits of energy-efficient windows, heating and cooling equipment, insulation, etc. Just over one-half (34 or 52%) of homeowners say they asked their builder or the sales agent about energy efficiency, which suggests there is a need for additional consumer education to encourage home buyers to ask builders and real estate agents about energy efficiency. Also, many owners who said they specified components of their new home said they did not specify energy-efficient or ENERGY STAR-qualified options, suggesting energy efficiency may not have been as important as they indicated when they rated the importance of getting an energy-efficient home. The following examples are based on 65 of the 69 inspected homes; not included are three new homes and one gut rehab home where the owner was also the builder. Discussion of the actual energy efficiency of homes is based on HERS ratings—the lower the HERS rating, the more energy-efficient the home.

The homes of owners who said getting an energy-efficient home was important in their decision to buy or build their home have an average HERS rating of 81, which is only slightly more energy efficient than the average HERS rating of 82 for all inspected homes. Roughly two-thirds of owners (42 of 65) rated the importance of getting an energy-efficient home 8 or higher on a scale of 0 to 10, but only half of these owners think their home is much more or somewhat more energy efficient than other new homes. These 42 homes include the most energy-efficient home inspected (HERS 62) and two of the three least energy-efficient homes inspected (HERS 102). Almost half (43%) of these 42 homes have HERS ratings that are higher (less energy efficient) than the average HERS rating for all inspected homes. There are several plausible reasons why homes of owners who said getting an energy-efficient home was important are not that energy efficient. Many home buyers do not have the language or understanding to know what to request when buying or building a home. Many home buyers do not have the knowledge to accurately assess the energy efficiency of their home. They may have no idea whether or not they have 2 x 6 framing let alone the importance of sealing and insulation. Or, they may think any home with 2 x 6 framing is energy efficient. They may simply take the builder's word that a home is energy efficient. They may start out wanting the most energy-efficient options, but when budget limitations come into play the first things to go are 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 study to assess the energy efficiency of their home and felt they should say energy efficiency was important. Remember, none of the inspected homes participated in the Connecticut RNC Program.

In most cases, owners who said they specified components of their home important to efficiency did not specify an energy-efficient or ENERGY STAR-labeled component. Of the 65 owners who did not build their own home, 77% (or 50 owners) said they specified aspects of one or more of the following components of their home: heating system, cooling system, water heater, windows, kitchen appliances, or lighting. Seventy percent of these 50 owners (35 owners) also ranked the importance of getting an energy-efficient home in their decision to build or purchase their home an 8, 9 or 10 on a scale of 0 (not important) to 10 (very important). However, when it came to specifying components of their home, it appears energy efficiency was not really a high priority for many of these owners. For most components, fewer than half of the owners who specified the component specified an energy-efficient or ENERGY STAR-qualified option: 8 of 18 (44%) who specified aspects of the heating system, 4 of 16 (25%) who specified aspects of the cooling system, 7 of 19 (37%) who specified aspects of the water heater, and 11 of 37 (30%) who specified aspects of the lighting. Owners were more likely to specify energy-efficient or ENERGY STAR-qualified windows (17 of 22 owners or 77%) and kitchen appliances (32 of 49 owners or 65%). Some owners indicated only that they specified a component of their home, without indicating what aspects of that component they specified. Owners who did identify the aspects of the components they specified, but did not specify energy-efficient or ENERGY STAR-labeled components, said they specified one or more of the following: the heating or water heating fuel; the type of heating, cooling or water heating system; whether or not to install central air conditioning; appliance fuel (gas or electric), style, brand, and/or color; the style of lighting fixtures. (See Section 6 Homeowner On-Site Survey for more information.)

## *Remainder of the Report*

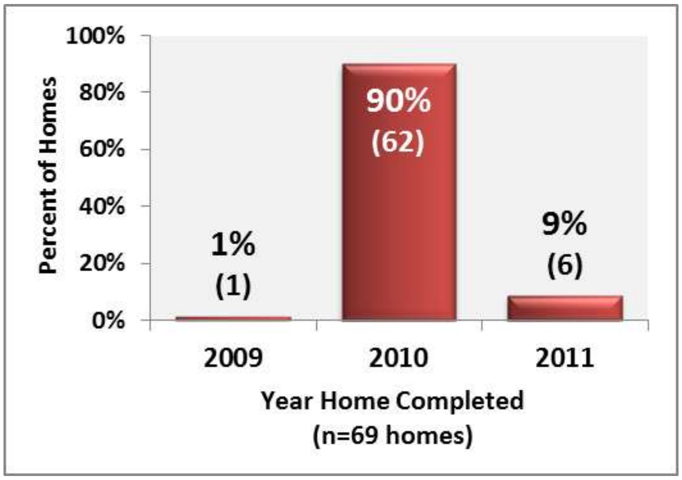
Detailed information supporting the findings presented in this executive summary is provided in the body of the report. Section 2 Sampling Methodology describes the sampling plan and Section 4 Comparison to Previous Baseline Study Findings compares 2011 Baseline Study findings to previous baseline study findings and UDRH inputs as well as current UDRH inputs. Appendix D Insulation Grades and Appendix E 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

KEMA auditors conducted on-site audits at 69 recently completed non-ENERGY STAR-qualified homes in 61 cities and towns across Connecticut. Figure 1-1 shows 1% of inspected homes were completed in 2009, 90% in 2010, and 9% in 2011.

**Figure 1-1: Year Homes Completed***




*Number of homes in parentheses.

Homes were inspected from late June through late October of 2011 with three primary objectives in mind:

- Providing a baseline of 69 non-ENERGY STAR-qualified homes recently completed across Connecticut that can be used to update baseline home assumptions used in calculating energy savings for Connecticut's Residential New Construction Program.
- Providing a comparison of the characteristics of custom-built versus spec-built homes.
- Conducting a full HERS rating for each home using REM/Rate software.

## *1.1 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, we estimated that a sample size of at least 63 homes would be adequate to produce a final precision of ± 10% at the 90% confidence level. As a result of this study we are 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 the 2011 Connecticut Baseline Study, duct leakage and air infiltration were 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.

Table 1-1 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 ± 1.0% for all fossil-fuel fired heating system efficiencies to ± 10.6% for duct leakage. The HERS index, which is the one measurement that addresses multiple building components, has a coefficient of variation of 0.10 and a very good relative precision of ± 2.0% at the 90% confidence level.

**Table 1-1: Coefficients of Variation for Key Residential Construction Measurements**

| Parameter | Sample Size | Coefficient of Variation | Relative Precision |
|---:|---|---|---|
| **All Fossil-Fuel Fired Heating System AFUE** | 70 | 0.05 | ±1.0% |
| **Central Air Conditioning SEER** | 76 | 0.06 | ±1.1% |
| **HERS Index** | 69 | 0.10 | ±2.0% |
| **Conditioned/Ambient Wall Insulation R-Value** | 69 | 0.11 | ±2.1% |
| **Cathedral Ceiling Insulation R-Value** | 20 | 0.21 | ±7.8% |
| **Cathedral Ceiling Insulation R-Value** | 68 | 023 | ±4.6% |
| **Air Infiltration—Air Changes per Hour at 50 Pascals** | 68 | 0.35 | ±6.9% |
| **Duct Leakage—CFM25/100 Sq. Ft.** | 61 | 0.51 | ±10.6% |

## 1.2 On-Site Data Collection

An on-site data collection form that contained the inputs required to conduct a full HERS rating was developed. The data collection form was broken up into five primary sections that are detailed in Table 1-2. (Appendix G Data Collection Form)

**Table 1-2: Data Collection Form Inputs**

| General Information | Insulation/Shell Measures | Mechanical Equipment | Test Results | Lighting & Appliances |
|---|---|---|---|---|
| • House type<br>• Area of conditioned space<br>• Volume of conditioned space<br>• Primary heating fuel<br>• Stories<br>• Bedrooms<br>• Thermostat type<br>• Builder type<br>• Own/Rent<br>• Evaluation region | • Exterior walls<br>• Ceilings<br>• Frame floors<br>• Rim/Band joists<br>• Windows<br>• Skylights<br>• Doors<br>• Slab Floors<br>• Foundation walls<br>• Mass walls<br>• Sunspaces | • Heating equipment<br>• Water heating equipment<br>• Cooling equipment<br>• Duct insulation<br>• Renewables | • Blower door results<br>• Duct blaster results | • CFL fixtures<br>• Incandescent or Halogen fixtures<br>• Fluorescent tube fixtures<br>• LED fixtures<br>• Ceiling Fans<br>• Refrigerators<br>• Dishwashers |

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. Framing was relatively easy to determine based on the depth of 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 D Insulation Grades for the 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 walkout basement and assigned a Grade II installation, then the above grade walls for that home were also assigned a Grade II installation.

Figure 1-2 shows a Grade I and a Grade III attic insulation installation.

**Figure 1-2: Example of Grade I and Grade III Attic 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 cellulose insulation in attics.

Defining a basement as conditioned, unconditioned, or both is a critical step in evaluating a home’s energy efficiency. For this study, a basement was considered conditioned under the following conditions:

- The basement was directly conditioned.
- The basement was finished and indirectly conditioned by an adjoining room.
- The basement was unfinished, indirectly conditioned, and the thermal boundary was clearly the basement walls, not the frame floor separating the basement from the first floor.

Any basement that did not meet one of these three requirements was considered an unconditioned basement. A few homes had basements that were both conditioned and unconditioned; one section of the basement was finished and directly conditioned while the other was unfinished and was not conditioned.

Duct sealing was almost always unobservable as insulation was covering the ducts, preventing visual verification of duct sealing. Similarly, it was often impossible to verify that building cavities were not being used as supply ducts, as most building cavities are enclosed once construction is complete.

# 2 Sampling Methodology

The sampling methodology involved developing a sample of new homes from utility new residential permanent service requests and the selection of homes for the on-site inspections based on their location and whether they were spec- or custom-built.

## *2.1 Sample Development*

The sample of homes for the on-site inspections was developed from new residential permanent service requests collected by Connecticut Light and Power and United Illuminating. New permanent service requests have been used as an unbiased way to identify newly constructed homes for baseline studies and new home buyer surveys in neighboring states over the past few years. However, new service requests may also involve additions to existing homes and other major renovations which must be screened out in scheduling the on-site inspections.

## *2.2 Data Cleaning*

The sample for the on-site inspections was drawn from permanent new service requests received by Connecticut Light and Power and United Illuminating after January 1, 2010. The new service requests were cleaned to remove addresses where:

- The home had participated in Connecticut's Residential New Construction Program.
- The housing unit was obviously not a single-family home.
- There was only the builder's name on the utility record.

After eliminating the above addresses, there were 1,127 possible addresses to be considered for the on-site inspections.

## 2.3 Sample Selection

Table 2-1 presents the sampling plan, which is based on the number of one-unit building permits issued in Connecticut counties in 2010 and matching the percentage of on-site inspections in a county to the percentage of statewide one-unit permits issued in that county.

**Table 2-1: Sampling Plan**

| County | 2010 One-Unit Building Permits | Percent of State One-Unit Building Permits | Number of Targeted On-Site Inspections | Percent of Targeted On-Site Inspections |
|---|---|---|---|---|
| Fairfield | 546 | 21% | 14 | 20% |
| Hartford | 630 | 24% | 17 | 24% |
| Litchfield | 140 | 5% | 4 | 6% |
| Middlesex | 271 | 10% | 7 | 10% |
| New Haven | 452 | 17% | 12 | 17% |
| New London | 285 | 11% | 8 | 11% |
| Tolland | 166 | 6% | 4 | 6% |
| Windham | 142 | 5% | 4 | 6% |
| **Total** | **2,632** | **100%** | **70** | **100%** |

In addition to the specified number of on-site inspections by county, the study attempted to maintain a minimum of 60% 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.

### 2.3.1 Recruitment

As noted above, preliminary data cleaning yielded over one thousand potential addresses from which to recruit the 70 on-site inspections. However, the requirements for one inspection per community and the spec/custom mix meant that most of this sample could not be used. Initially, five new service request addresses were chosen at random from communities that had more than five available. Letters with the logos of the Connecticut Energy Efficiency Fund, Connecticut

Light and Power, and United Illuminating were mailed out to those customers introducing the study and offering payments of $150 to $200 (the latter for homes that participated in HVAC performance testing) for access to the homes. Customers were then selected at random from the list that had been sent letters and called to schedule on-sites.

Approximately one-half of the customers sent these letters were never contacted because the quota of inspections in a particular county was reached. Additionally, once an inspection was completed, every other contact in that community was considered ineligible; this meant that there were many homes that received a phone message about the survey but there was no further attempt to contact them. Of the customers who did speak with the recruiters over the telephone, slightly more than one-half agreed to the on-site visits.

### 2.3.2 Completed On-Site Inspections

As Table 2-2 shows, the completed on-site inspections followed the sampling plan shown in Table 2-1 and the desired spec/custom mix fairly closely. The study has a mix of 68% spec-built and 32% custom-built homes.

**Table 2-2: Completed On-Site Inspections**

| County | Targeted On-sites | Completed On-Sites | Spec-built | Custom-built |
|---|---|---|---|---|
| **Fairfield** | 14 | 14 | 10 | 4 |
| **Hartford** | 17 | 16 | 11 | 5 |
| **Litchfield** | 4 | 3 | 2 | 1 |
| **Middlesex** | 7 | 7 | 4 | 3 |
| **New Haven** | 12 | 13 | 9 | 4 |
| **New London** | 8 | 8 | 6 | 2 |
| **Tolland** | 4 | 4 | 3 | 1 |
| **Windham** | 4 | 4 | 2 | 2 |
| **Total** | **70** | **69** | **47** | **22** |

Moreover, the inspections took place in 61 cities and towns across Connecticut; there was only one inspection done in 53 communities and two inspections done in each of eight communities. The 61 communities covered are shown in Figure 2-1.

**Figure 2-1: On-site Inspections**

Table 2-3 presents summary economic characteristics by county. Most on-sites were conducted in counties where the median value of owner-occupied housing units and the median household income are below the statewide medians. Forty-one out of 69 on-sites or 59% were conducted in counties where the median value of owner-occupied housing units is below the statewide median and 48 out of 69 on-sites or 70% were conducted in counties where the median household income is below the statewide median.

**Table 2-3: Economic Characteristics by County**

| County | Completed On-Sites | Median Value of Owner-Occupied Units* | Median Household Income* |
|---|---|---|---|
| **Fairfield** | 14 | $484,200 | $78,892 |
| **Hartford** | 16 | $242,900 | $61,962 |
| **Litchfield** | 3 | $287,200 | $67,688 |
| **Middlesex** | 7 | $303,100 | $74,524 |
| **New Haven** | 13 | $271,500 | $60,388 |
| **New London** | 8 | $263,800 | $63,450 |
| **Tolland** | 4 | $257,600 | $78,471 |
| **Windham** | 4 | $226,300 | $56,342 |
| **Total Connecticut** | **69** | **$295,800** | **$66,906** |

*http://quickfacts.census.gov/qfd/states/09/09001.html; median home values are for the years 2005 through 2009; median income is for the year 2009

There is considerable variation in economic characteristics among the cities and towns within each county, so Table 2-4 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 and incomes above the statewide median.

**Table 2-4: Economic Characteristics by Community**

| County | Median Value of Owner-Occupied Units* | Median Household Income* |
|---|---|---|
| **On-Sites in Communities Above State Median** | 41 (60%) | 52 (76%) |
| **On-Sites in Communities Below State Median** | 27 | 16 |
| **On-Sites in Communities Without Data** | 1 | 1 |

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

# 3 Preliminary UDRH Input Estimates

The 2011 preliminary UDRH inputs presented in this section are preliminary estimates based on study findings. This section presents detailed information showing the data used to develop the estimated UDRH inputs. Program Administrators will review these data and preliminary UDRH estimates when developing a final set of UDRH inputs.

## 3.1 Unverifiable Building Components and Characteristics

Some building and component characteristics are often impossible to verify in a post-construction inspection. Examples are slab insulation, because it is generally not visible; window U-values and SHGC coefficients, because the original NFRC stickers are no longer available; and door U-values because, like windows, the NFRC stickers are no longer available. Also, none or very few inspected homes have certain types of mechanical equipment.

### 3.1.1 Slab Floor Insulation

Auditors were unable to observe underneath the slabs post construction and, therefore, were able neither to confirm the existence of nor record the R-values of slab floor insulation. Whenever possible, auditors estimated unobservable building characteristics based on building plans or discussions with homeowners.

### 3.1.2 Window U-values and Solar Heat Gain Coefficients

Because inspections were conducted post construction at occupied homes, auditors were able to verify very few window U-values and Solar Heat Gain Coefficients (SHGC) and no skylight efficiency information; NFRC (National Fenestration Rating Council) stickers were not available for any skylights and window NFRC stickers were available at only two homes. Representatives of 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 Connecticut are U-0.32 or lower, depending on the SHGC. We propose an overall default window U-value of 0.34; this may be conservative, but 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.

### 3.1.3 Door U-values

Auditors were unable to verify the U-values of doors because the original NFRC sticker was no longer present on any door. Based on conversations with staff personnel at four Connecticut lumber yards that sell doors to builders of new homes we propose that a conservative default door U-Value would be in the 0.30 range. A U-0.30 door is measurably lower than the 2006 and 2009 IECC prescriptive maximum of U-0.35 and measurably higher than if all doors were assumed to just meet ENERGY STAR criteria.

### 3.1.4 Mechanical Equipment not Observed

It goes beyond the scope of this baseline study to estimate average efficiencies for types of mechanical equipment not observed in inspected homes. None of the inspected homes have an air source heat pump, electric resistance heating system, or kerosene heating system; only one home has a ground source heat pump and only one home has a natural gas boiler. No inspected homes have heat pump or solar water heaters. One possible approach the program administrators could use for estimating the UDRH input for heat pump water heaters would be to assume they have the same efficiency as conventional electric water heating systems; this is an approach being used by some residential new construction programs.

## 3.2 Wall, Ceiling and Floor Insulation

UDRH input estimates for above grade walls, floors and ceilings are U-values calculated by REM/Rate. Per RESNET standards there are three insulation installation grades: Grade I, Grade II, and Grade III. Auditors applied these insulation grades to all insulation components. In order to model a full HERS rating in REM/Rate these grades were assigned to individual insulation components in the software. The evaluation team used REM/Rate outputs to compile the UDRH estimates for this study and these U-values account for the insulation installation grades applied to each insulation component.

REM/Rate software models insulation grades in the following manner. If a component was designated as Grade I then the component is considered to have no missing insulation, if it was designated as Grade II then it is considered to have a 2% void, and if it was designated as Grade III then it is considered to have a 5% void in insulation.

## 3.3 UDRH Input Data

The following tables show the number of homes or observations on which the 2011 Baseline preliminary UDRH estimates are based. This study reports on what was found in the 69 inspected homes. As noted above, it is beyond the scope of this study to estimate average efficiencies for types of mechanical equipment not observed in the inspected homes. However, UDRH inputs for window and door U-values are proposed based on secondary research.

**Table 3-1: UDRH Wall Input Data**

| UDRH Above Grade Wall Inputs (U-values or R-values) | Current UDRH | 2011 Baseline Prelim. Estimate | Number of Observations or Homes | Min. | Max. | Average | Median |
|---|---|---|---|---|---|---|---|
| Conditioned/Ambient Uo | 0.070 | 0.068 | 69 | 0.046 | 0.098 | 0.068 | 0.067 |
| Unconditioned/Ambient Uo | 0.300 | 0.098 | 27 | 0.039 | 0.371 | 0.098 | 0.067 |
| Foundation Wall R-value | n/a | 17.3 | 18 | 0 | 27.0 | 17.3 | 19.0 |
| Rim & Band Joist Insulation (Unconditioned Basement/ Ambient) R-value | n/a | 6.9 | 18 | 0 | 24 | 6.9 | 0 |

**Table 3-2: UDRH Ceiling Input Data**

| UDRH Ceiling Inputs Ceiling Uo | Current UDRH Input | 2011 Baseline Prelim. Estimate | Number of Observations or Homes | Min. | Max. | Average | Median |
|---|---|---|---|---|---|---|---|
| **Attic Uo** | 0.0384 | 0.0441 | 68 | 0.0175 | 0.0672 | 0.0441 | 0.0496 |
| **Vaulted Uo** | 0.0534 | 0.0417 | 20 | 0.0213 | 0.0598 | 0.0417 | 0.0422 |

**Table 3-3: UDRH Frame Floor Input Data**

| UDRH Frame Floor Inputs Frame Floor Uo | Current UDRH Input | 2011 Baseline Preliminary Estimate | Number of Observations or Homes | Min. | Max. | Average | Median |
|---|---|---|---|---|---|---|---|
| **Conditioned/Basement Uo** | 0.070 | 0.074 | 57 | 0.034 | 0.257 | 0.074 | 0.049 |
| **Conditioned/Garage Uo** | 0.052 | 0.075 | 30 | 0.034 | 0.257 | 0.075 | 0.046 |
| **Conditioned/Open Crawl Space Uo** | 0.070 | 0.103 | 4 | 0.043 | 0.257 | 0.103 | 0.056 |
| **Conditioned/Ambient Uo** | 0.060 | 0.047 | 11 | 0.035 | 0.060 | 0.047 | 0.046 |

**Table 3-4: Proposed UDRH Window Input**

| UDRH Window U-value Input |
|---|
| The current UDRH window U-value input is U-0.35. NFRC (National Fenestration Rating Council) stickers were found at only two homes. Both homes are spec homes and both have Low-E with argon, vinyl framed windows with a U-value of 0.31. Based on secondary information, a default value of U-0.30 is proposed. |

**Table 3-5: Proposed UDRH Door Input**

| UDRH Door U-value Input |
|---|
| The current UDRH door U-value input is U-0.268. NFRC stickers were no longer present on any doors in inspected homes. Based on secondary information, a default value of U-0.30 is proposed. |

**Table 3-6: UDRH Foundation Wall Input Data**

| Foundation Wall Insulation Conditioned Basement to Ambient | Current UDRH Input | 2011 Baseline Preliminary Estimate | Number of Observations or Homes | Min. | Max. | Average | Median |
|---|---|---|---|---|---|---|---|
| **Conditioned Basement/ Ambient R-value** | Reference Home Same as As-Built Home | 17.3 | 18 | 0.0 | 27.0 | 17.3 | 19 |

### Table 3-7: UDRH Slab Floor Input

| UDRH Slab Floor Input |
|---|
| Currently there is no UDRH input for slab floors. The reference home is assumed to be the same as the as-built home. Auditors were unable to verify either the existence of or the R-value of slab floor insulation post construction. |

### Table 3-8: UDRH Cooling Input Data

| Cooling System Efficiency | Current UDRH Input | 2011 Baseline Prelim. Estimate | Number of Observations or Homes | Min. | Max. | Average | Median |
|---|---|---|---|---|---|---|---|
| **Electric Central AC SEER (nameplate)** | 13 SEER | 13.4 SEER | 76 | 13.0 | 16.0 | 13.4 | 13.0 |

### Table 3-9: UDRH Heating System Input Data

| UDRH Heating System Inputs AFUE, SEER or HSPF[13] | Current UDRH Input | 2011 Baseline Prelim. Estimate | Number of Observations or Homes | Min. | Max. | Average | Median |
|---|---|---|---|---|---|---|---|
| **All Oil Heating Systems** | **83.3 AFUE** | **84.5 AFUE** | **14 Oil Boilers & Furnaces** | **80.5** | **87.5** | **84.5** | **85.3** |
| | | | 11 Oil Boilers | 83.6 | 87.5 | 85.3 | 85.3 |
| | | | 3 Oil Furnaces | 80.5 | 83.4 | 81.6 | 81.0 |
| **All Kerosene Heating Systems** | **83.3 AFUE** | **n/a** | **No Homes** | **n/a** | **n/a** | **n/a** | **n/a** |
| **All Natural Gas Heating Systems** | **90 AFUE** | **92.4 AFUE** | **26 Nat. Gas Boilers & Furnaces** | **80.0** | **95.5** | **92.4** | **92.4** |
| | | | 1 Natural Gas Boiler | 95.0 | 95.0 | 95.0 | 95.0 |
| | | | 25 Natural Gas Furnaces | 80.0 | 95.5 | 92.3 | 92.3 |
| **All Propane Heating Systems** | **87.1 AFUE** | **92.1 AFUE** | **30 Propane Boilers & Furnaces** | **80.0** | **98.0** | **92.1** | **92.1** |
| | | | 6 Propane Boilers | 82.0 | 97.3 | 89.6 | 90.0 |
| | | | 24 Propane Furnaces | 80.0 | 98.0 | 92.8 | 92.1 |
| **Electric Resistance Heating Systems** | **100 AFUE** | n/a | No Homes | n/a | n/a | n/a | n/a |
| **Air Source Heat Pumps (ASHP)** | 13 SEER | n/a | No Homes | n/a | n/a | n/a | n/a |
| **Electric Ground Source Heat Pumps** | 7.7 HSPF | 17.4 HSPF | 1 Ground Source Heat Pump | 17.4 HSPF | 17.4 HSPF | 17.4 HSPF | 17.4 HSPF |

13 Heating Season Performance Factor.

### Table 3-10: UDRH Water Heating Input Data

| Water Heating | Current UDRH Input | 2011 Baseline Prelim. Estimate | Number of Observations or Homes | Min. | Max. | Average | Median |
|---|---|---|---|---|---|---|---|
| Electric Conventional Energy Factor | .90 EF | .90 EF | 13 | 0.86 | 0.95 | 0.90 | 0.91 |
| Recovery Efficiency | 98% RE | 98% RE | 13 | 98% | 98% | 98% | 98% |
| Gallons | 54 | 56 | 13 | 40 | 80 | 56 | 50 |
| Oil Conventional Energy Factor | .61 EF | .63 EF | 1 | 0.63 | 0.63 | 0.63 | 0.63 |
| Recovery Efficiency | 77% RE | 80% RE | 1 | 80% | 80% | 80% | 80% |
| Gallons | 49 | 32 | 1 | 32 | 32 | 32 | 32 |
| Oil Integrated Energy Factor | .69 EF | .79 EF | 6 | 0.78 | 0.81 | 0.79 | 0.79 |
| Recovery Efficiency | 77% RE | 80% RE | Same as Oil Conventional | | | | |
| Gallons | 49 | 49 | 6 | 40 | 80 | 49 | 43 |
| Natural Gas Conventional EF | .58 EF | .62 EF | 13 | 0.50 | 0.65 | 0.62 | 0.63 |
| Recovery Efficiency | 73% RE | 79% RE | 12 | 76% | 81% | 79% | 80% |
| Gallons | 46 | 48 | 13 | 40 | 75 | 48 | 40 |
| Natural Gas Integrated Energy Factor | .75 EF | .87 EF | 1 | 0.87 | 0.87 | 0.87 | 0.87 |
| Recovery Efficiency | 73% RE | 79% RE | Same as Natural Gas Conventional | | | | |
| Gallons | 46 | 50 | 1 | 50 | 50 | 50 | 50 |
| Natural Gas Instantaneous EF | Deemed Savings (PSD) | .92 EF | 8 | 0.82 | 0.98 | 0.92 | 0.95 |
| Recovery Efficiency | | 93% RE | 8 | 83% | 98% | 93% | 97% |
| Propane Conventional Energy Factor | .56 EF | .60 EF | 12 (Includes 3 large tanks) | 0.50 | 0.65 | 0.60 | 0.63 |
| Propane Conventional Energy Factor | .56 EF | .63 EF | 9 (Excludes 3 large tanks) | 0.58 | 0.65 | 0.63 | 0.63 |
| Recovery Efficiency | 76% RE | 80% RE | 8 | 76% | 82% | 80% | 80% |
| Gallons | 50 | 52 | 12 (Includes 3 large tanks) | 40 | 75 | 52 | 50 |
| Gallons | 50 | 44 | 9 (Excludes 3 large tanks) | 40 | 50 | 44 | 40 |
| Propane Integrated Energy Factor | .56 EF | .88 EF | 2 | 0.87 | 0.90 | 0.88 | 0.88 |
| Recovery Efficiency | 76% RE | 80% RE | Same as propane conventional | | | | |
| Gallons | 50 | 65 | 2 | 50 | 80 | 65 | 65 |
| Propane Instantaneous Energy Factor | Deemed Savings (PSD) | .86 EF | 7 | 0.82 | 0.95 | 0.86 | 0.82 |
| Recovery Efficiency | | 88% RE | 7 | 81% | 98% | 88% | 84% |

**Table 3-11: UDRH Duct Insulation Input Data**

| Duct Insulation | Current UDRH Input | 2011 Baseline Prelim. Estimate | Number of Observations or Homes | Min. | Max. | Average | Median |
|---|---|---|---|---|---|---|---|
| Attic--Supply Ducts | R-4.6 | R-7.7 | 51 | R-6.0 | R-10.0 | R-7.7 | R-8.0 |
| Attic--Return Ducts | R-4.6 | R-7.4 | 51 | R-6.0 | R-10.5 | R-7.4 | R-7.0 |
| All Unconditioned Space--Supply Ducts | R-4.6 | R-7.4 | 62 | R-4.0 | R-10.3 | R-7.4 | R-7.6 |
| All Unconditioned Space--Return Ducts | R-4.6 | R-6.8 | 62 | R-0.0 | R-10.0 | R-6.8 | R-6.7 |

**Table 3-12: UDRH Duct Leakage Input Data**

| Duct Leakage | Current UDRH Input | 2011 Baseline Prelim. Estimate | Number of Observations or Homes | Min. | Max. | Average | Median |
|---|---|---|---|---|---|---|---|
| CFM25/100 $ft^2$ CFA | 17.7 | 17.3 | 61 | 5.0 | 46.4 | 17.7 | 15.9 |

**Table 3-13: UDRH Air Infiltration Input Data**

| UDRH Infiltration Inputs CFM50, ACH50, ACHnat | Current UDRH Input | 2011 Baseline Prelim. Estimate | Number of Observations or Homes | Min. | Max. | Average | Median |
|---|---|---|---|---|---|---|---|
| CFM50 | n/a | 2,179 | 69 | 729 | 6,395 | 2,179 | 2,084 |
| Heating Season ACHnat | 0.39 | 0.33 | 69 | 0.16 | 0.78 | 0.33 | 0.32 |
| Cooling Season ACHnat | 0.25 | 0.25 | 69 | 0.12 | 0.58 | 0.25 | 0.23 |
| ACH50 (Air Changes per Hour @ 50 Pascal) | n/a | 5.8 | 69 | 3.0 | 13.1 | 5.8 | 5.6 |

# 4 Comparison to Previous Baseline Study Findings

This section compares 2011 Baseline Study findings to previous baseline study findings and UDRH inputs. Wherever possible, 2011 Baseline Study findings are compared to the following:

- UDRH inputs in place prior to the 2001 Baseline Study[14] of Connecticut homes, based on Council of American Building Officials Model Energy Code-1995 Edition (MEC 95) minimum requirements[15]
- Findings from the 2001 Baseline Study conducted by RLW Analytics
- Current UDRH inputs

Before discussing how construction practices have changed from one study to another it is important to understand the similarities and differences in the studies. There are several similarities: the 2001 and 2011 studies both limited inspections to homes that did not participate in a Connecticut residential new construction program, sampling plans ensured the final sample of inspected homes represented building activity across the state, blower door tests were conducted at all homes, and REM/Rate software was used to analyze data. However, as shown below, there are significant differences in how sample homes were recruited.

### *2001 Baseline Study Sample*

- Recruited builders and inspected one to four homes per builder
- Inspected 65 recently completed, unoccupied single-family homes built by 42 different builders
- Unable to recruit any of the six largest builders in the state who built about one third of all new homes in the state.[16]

### *2011 Baseline Study Sample*

- Recruited owners of recently completed homes
- Inspected 69 recently completed homes in 61 different cities and towns across Connecticut
- Based on information provided by the owners, inspected homes were built by at least 65 different builders.

These differences in how homes were recruited impact study findings in two major ways. First, recruiting homes through builders generally results in a sample biased toward more energy-efficient construction because builders who are not building to meet code requirements or who do not think their homes are at least relatively energy efficient are unlikely to agree to having their homes inspected. Second, inspecting new unoccupied homes and working with the builders of those homes means you are much more likely than when conducting post construction

[14] *Baseline Evaluation for the Energy Star Home New Construction Program Final Report*. Prepared by RLW Analytics for Northeast Utilities Service Company and United Illuminating Company. January 2002.
[15] Ibid. p. 22.
[16] Ibid. p. 9.

inspections of occupied homes to get accurate information on window U-values and Solar Heat Gain Coefficients (SHGC), door U-values, slab insulation and exterior foundation wall insulation.

The tables in this section are in the same basic format as the table in the 2001 Baseline Study report that compared then current UDRH inputs to 2001 study findings. The gray shaded rows and cells are not UDRH inputs—they either indicate where comparable data were not available or contain explanatory information for readers that is comparable to what was provided in 2001 Baseline Study tables. The 2011 information provides the observed nominal R-value of insulation as well as the U-value of the assembly and 1/U-value (an estimate of the effective R-value of a component assembly). In some cases there is a large difference between the observed R-value and the effective R-value (1/U-value). These differences reflect the impact of the different framing and insulation installation grades that are accounted for in the REM/Rate software calculation of assembly U-values; the lower the grade of the insulation installation the bigger the difference between the nominal and effective R-value. (See Appendix D Insulation Grades.)

Overall, compared to 2001 Baseline Study findings, 2011 Baseline Study findings show:

- Lower U-value (more efficient) conditioned/ambient and unconditioned/ambient wall assemblies
- Lower U-value (more efficient) flat ceiling (attic) assemblies and higher U-value (less efficient) cathedral (vaulted) ceiling assembles
- Higher U-value (less efficient) floor assemblies except for conditioned/ambient floors, which have a lower U-value (more efficient)
- Higher U-value (less efficient) unconditioned basement/ambient rim joist assemblies
- Higher insulation levels for conditioned basement/ambient foundation walls
- Air infiltration—heating season natural air changes per hour (ACHnat) are lower and cooling season ACHnat unchanged.
- Duct insulation levels are higher in 2011, but duct leakage is similar to 2001 findings.
- Heating system AFUEs are higher.
- In both studies, cooling system Seasonal Energy Efficiency Ratios (SEERs) are just slightly higher than the federal minimum efficiency standard in effect at the time of the study.
- Most types of water heating systems have higher Energy Factors and recovery efficiencies.
- The penetration of energy-efficient lighting has increased.

Table 4-1 shows the average U-value of conditioned/ambient wall assemblies improved from the pre 2001 UDRH input of 0.120 to 0.070 in the 2001 study, which is the current UDRH input, to 0.068 in the 2011 study. The average U-value of above grade unconditioned/ambient wall assemblies is much lower (more efficient) in 2011 baseline homes, $U_0$= 0.098 in 2011 compared to $U_0$= 0.300 earlier. The walls included in this category in the 2011 study are above grade wood-framed unconditioned basement/ambient walls.

Table 4-1 also shows that the average U-value of attic (flat) ceilings is higher (less efficient) in 2011 baseline homes ($U_0$=0.0441) than in 2001 baseline homes or the current UDRH input, both of which are $U_0$=0.0384. At the same time, the U-value of cathedral (vaulted) ceilings is lower (more efficient) in 2011 baseline homes ($U_0$=0.0417) than in 2001 baseline homes or the current UDRH input, both of which are $U_0$=.0.0534.

**Table 4-1: Walls and Ceilings**

| Home Feature | Pre 2001 UDRH MEC 95 | 2001 Baseline | Current UDRH | 2011 Baseline Preliminary UDRH Input |
|---|---|---|---|---|
| **Above Grade Wall Insulation (Conditioned to Any)** | | | | |
| **Conditioned/Ambient: Uo Value** | $U_o$ Value = 0.120 | $U_o$ Value = 0.070 | Uo Value =0.070 | Uo Value =0.068 |
| *Above Grade Wall Insulation: R-value* [a] | *1/Uo ≈ R-8.3* | *1/Uo ≈ R-14.3* | *1/Uo ≈ R-14.3* | *1/Uo ≈ R-14.7 Installed R-19.0* |
| **Above Grade Wall Insulation (Unconditioned to Any)** | | | | |
| **Unconditioned Basement/Ambient Uo** | Uo Value =0.300 | Uo Value =0.300 | Uo Value =0.300 | Uo Value =0.098 |
| *Above Grade Wall Insulation: R-value* [a] | *1/Uo ≈ R-3.3* | *1/Uo ≈ R-3.3* | *1/Uo ≈ R-3.3* | *1/Uo ≈ R-10.2 Installed R-18.2* |
| **Ceiling Insulation** | | | | |
| **Attic Ceiling Insulation: Uo Value** | n/a | $U_o$ Value = 0.0384 [b] | $U_o$ Value = 0.0384 | Uo Value =0.0441 |
| *Attic Ceiling Insulation: R-value* [a] | n/a | *1/Uo ≈ R-26.0* | *1/Uo ≈ R-26.0* | *1/Uo ≈ R-22.7 Installed R-33.6* |
| **Vaulted Ceiling Insulation: Uo Value** | n/a | $U_o$ Value = 0.0534 [b] | $U_o$ Value = 0.0534 | Uo Value =0.0417 |
| *Vaulted Ceiling Insulation: R-value* [a] | n/a | *1/Uo ≈ R-18.7* | *1/Uo ≈ R-18.7* | *1/Uo ≈ R-24.0 Installed R-31.9* |
| *All Ceiling Insulation: $U_0$ Value* | $U_o$ Value = 0.0260 | n/a | n/a | n/a |
| *All Ceiling Insulation: R-value* [a] | *1/Uo ≈ R-38.5* | n/a | n/a | n/a |

[a] Not a UDRH input—provided only for information.

[b] From 2001 Baseline Study: The current UDRH value is a 0.026 composite for all ceiling features, including skylights. RLW's study results suggest that the UDRH should have an attic ceiling type Uo value of 0.0384 and a cathedral Uo value of 0.0534.[17]

[17] *Baseline Evaluation for the Energy Star Home New Construction Program Final Report*. Prepared by RLW Analytics for Northeast Utilities Service Company and United Illuminating Company. January 2002, p 24.

Table 4-2 shows that the average U-values of conditioned/unconditioned basement, conditioned/garage, and conditioned/open crawlspace floor assembles are higher (less efficient) in 2011 baseline homes than in 2001 baseline homes and higher than current UDRH inputs (current UDRH inputs are the same as 2001 baseline findings). Looking at 2011 results for these floors, the differences between observed nominal R-values and effective R-values ($1/U_0$) are large, reflecting very few Grade I insulation installations.

At the same time, Table 4-2 shows that the average U-value of conditioned/ambient floor assemblies in 2011 baseline homes ($U_0$=0.047) is lower (more efficient) than the pre 2001 UDRH input of $U_0$=0.50, the 2001 Baseline Study $U_0$=0.065, and the current UDRH input $U_0$=0.060. One key factor in the lower average U-value of conditioned/ambient floors in 2011 baseline homes is that all the conditioned/ambient floors observed in inspected homes were insulated, while for all other floor categories there were some that were not insulated.

As shown, there currently is no slab insulation UDRH input—the reference home is the same as the as-built home. Also, as noted, auditors of 2011 baseline homes were unable to either confirm the existence of or level of slab insulation post construction.

**Table 4-2: Floors and Slabs**

| Home Feature | Pre 2011 Baseline UDRH MEC 95 | 2001 Baseline | Current UDRH | Baseline Preliminary Estimated UDRH Input |
|---|---|---|---|---|
| **Frame Floor Insulation (Conditioned to Buffer)** | | | | |
| **All Conditioned/Buffer (Cond. over Uncond. Basement) Uo Value** | $U_o$ Value = 0.25 | $U_o$ Value = 0.070 | $U_o$ Value = 0.070 | $U_o$ Value = 0.074 |
| *R-value* [a] | *1/Uo ≈ R-4* | *1/Uo ≈ R-14.3* | *1/Uo ≈ R-14.3* | *1/Uo ≈ R-13.5, Installed R-20.5* |
| **Conditioned/Garage Floor $U_0$ Value** | $U_o$ Value = 0.05 | $U_o$ Value = 0.052 | $U_o$ Value = 0.052 | $U_o$ Value = 0.075 |
| *R-value* [a] | *1/Uo ≈ R-20* | *1/Uo ≈ R-19.2* | *1/Uo ≈ R-19.2* | *1/Uo ≈ R-13.3, Installed R-22.1* |
| **Conditioned/Open Crawlspace $U_0$ Value** | $U_o$ Value = 0.05 | $U_o$ Value = 0.070 | $U_o$ Value = 0.070 | $U_o$ Value = 0.103 |
| *R-value* [a] | *1/Uo ≈ R-20* | *1/Uo ≈ R-14.3* | *1/Uo ≈ R-14.3* | *1/Uo ≈ R-9.7, Installed R-16.3* |
| **Conditioned/Ambient $U_0$ Value** | $U_o$ Value = 0.05 | $U_o$ Value = 0.065 | $U_o$ Value = 0.060 | 1/Uo ≈ 0.047 |
| *R-value* [a] | *1/Uo ≈ R-20* | *1/Uo ≈ R-15.4* | *1/Uo ≈ R-16.7* | *1/Uo ≈ R-21.3, Installed R-25.4* |
| **Slab Floor Insulation** | | | | |
| Under Slab Insulation R-Value | R- 6.0 | R-0.0 | Reference home (UDRH) same as the as-built home | Post construction: not able to confirm either existence of or R-values of slab floor insulation |

[a] Not a UDRH input—provided only for information.

Table 4-3 addresses rim and band joists and foundation walls. As shown, there currently are no UDRH inputs for these features, the UDRH or reference home is assumed to be the same as the as-built home. The average U-value of unconditioned basement/ambient rim joists in 2011 baseline homes is $U_0$=0.145, which is higher (less efficient) than the pre 2001 UDRH input of $U_0$=0.120 and the 2001 baseline $U_0$=0.055. The average U-value of unconditioned basement/ambient rim joists in 2011 baseline homes is $U_0$=0.145, which is higher (less efficient) than the pre 2001 UDRH input of $U_0$=0.120 and the 2001 baseline $U_0$=0.055.

The average U-value of conditioned basement/ambient walls in 2011 baseline homes is $U_0$=0.058, which is lower (more efficient) than the pre 2001 UDRH input of $U_0$=0.078 and much lower than the 2001 baseline $U_0$=0.392. The key factor in the difference between the 2001 and 2011 baseline results is that there were only five homes with conditioned basements in the 2001 study and only two of the five homes had insulated foundation walls. In the 2011 study, 15 of 18 homes with conditioned basements had R-10 continuous or R-13 cavity or higher insulation on foundation walls.

**Table 4-3: Rim and Band Joists and Foundation Walls**

| Home Feature | Pre 2011 Baseline UDRH MEC 95 | 2001 Baseline | Current UDRH | Baseline Preliminary Estimated UDRH Input |
|---|---|---|---|---|
| **Rim & Band Joist Insulation (Unconditioned Basement to Ambient)** | | | | |
| Rim & Band Joist Insulation Uo Value [a] | $U_o$ Value = 0.120 | $U_o$ Value = 0.055 | Reference home (UDRH) same as the as-built home | No REM U-value $U_0 \approx 1/R = 0.145$ |
| Rim & Band Joist Insulation R-value | R-8.3 | R-18.2 | | Installed R-6.9 |
| **Foundation Wall Insulation (Conditioned Basement to Ambient)** | | | | **Conditioned Basement to Ambient Masonry Walls** |
| *Foundation Wall Insulation Uo Value* [a] | *$U_o$ Value = 0.078* | *$U_o$ Value = 0.392* | Reference home (UDRH) same as the as-built home | No REM U-value, $U_0 \approx 1/R = 0.058$ |
| Foundation Wall Insulation R-value [a] | R-12.8 | R-2.6 | | Installed R-17.3 |

[a] Not a UDRH input—provided only for information.

Table 4-4 addresses exterior doors, windows and skylights. This is a case where the 2001 study, which recruited builders with recently completed, unoccupied homes, had much better access to NFRC stickers or builder information on door and window efficiencies. In the 2011 study, which recruited recently completed owner occupied homes, NFRC stickers were not available for any doors or skylights and window NFRC stickers were available at only two homes.

**Table 4-4: Exterior Doors, Windows and Skylights**

| Home Feature | Pre 2011 Baseline UDRH MEC 95 | 2001 Baseline | Current UDRH | Baseline Preliminary Estimated UDRH Input |
|---|---|---|---|---|
| **Exterior Doors (Conditioned to Ambient)** | | | | |
| **Exterior Doors Uo Value** | $U_o$ Value = 0.120 | $U_o$ Value = 0.268 | $U_o$ Value = 0.268 | Post construction, NFRC stickers no longer present on any doors: Propose U-0.30 for UDRH (See Doors) |
| **Windows** | | | | |
| **Windows: Uo Value** | $U_o$ Value = 0.120 | $U_o$ Value = 0.410 | $U_o$ Value = 0.35 | NFRC stickers at only two homes; both $U_0$ Value 0.31 Propose U- 0.34 for UDRH (See Windows) |
| *Windows: R-value* [a] | *1/Uo ≈ R-8.3* | *1/Uo ≈ R-2.4* | *1/Uo ≈ R-2.9* | |
| **Windows: SHGC** | SHGC = 0.570 | SHGC = 0.47 | SHGC = 0.35 | NFRC stickers at only two homes; one SHGC 0.30 and one 0.22 |
| **Skylights** | | | | |
| **Skylights: Uo Value** | $U_o$ Value = 0.026 [c] | $U_o$ Value = 0.446 [c] | $U_o$ Value = 0.446 | Five homes with skylights: No NFRC stickers. |
| *Skylights: R-value* [a] | *1/Uo ≈ R-38.5* | *1/Uo ≈ R-2.2* | *1/Uo ≈ R-2.2* | |
| **Skylights: SHGC** | n/a | n/a | SHGC = 0.31 | |

[a] Not a UDRH input—provided only for information.

[c] From 2001 Baseline Study: The current UDRH Uo value for skylights are part of a composite ceiling value calculated in MEC 95 to be 0.0260. However, RLW analyzed the specific Uo value of skylights independently as 0.446 in the on-sites and recommends that this be used in the current UDRH.[18]

[18] Ibid, p. 30.

Table 4-5 addresses air infiltration, duct insulation and duct leakage. As shown, the average heating season natural air changes per hour (ACHnat), calculated by REM/Rate, improved from 0.39 in the 2001 study to 0.33 in the 2011 study while cooling season ACHnat remained constant at 0.25. The 2011 study also reports average air changes per hour measured at 50 Pascals (ACH50) of 5.8. The 2001 and 2011 studies both conducted blower door tests at all inspected homes.

Average duct insulation levels are higher in 2011 baseline homes than in 2001 baseline homes. The categories are different in the two studies, but it is clear that ducts in 2011 baseline homes are better insulated. Duct leakage results show a different story. Duct blaster tests were performed on a sample of 44 of the 2001 baseline homes. The 2001 study reported average duct leakage of 478 CFM25. The 2011 study conducted duct leakage testing at 61 of the 64 inspected homes with duct systems—average leakage was 472 CFM25. The 2011 study also reports average CFM25/100 Square Feet of Conditioned Floor Area (CFA) of 17.7, which is very close to the current UDRH input of 17.3 CFM25/100 Square Feet of CFA.

**Table 4-5: Air Infiltration, Duct Insulation and Duct Leakage**

| Home Feature | Pre 2011 Baseline UDRH MEC 95 | 2001 Baseline | Current UDRH | Baseline Preliminary Estimated UDRH Input |
|---|---|---|---|---|
| **Infiltration & Ventilation** | | | | |
| Heating Season ACHnat | 0.50 | 0.39 | 0.39 | 0.33 |
| Cooling Season ACHnat | 0.50 | 0.25 | 0.25 | 0.25 |
| ACH50 | | | | 5.8 ACH50 |
| **Duct Insulation** | | | | |
| Location and R-value | Enclosed Crawlspace R-5.0 | Enclosed Crawlspace R-4.6 | Enclosed Crawlspace R-4.6 | Attic Supply R- 7.7 |
| Location and R-value | Open Crawlspace R-6.5 | Open Crawlspace R-4.6 | Open Crawlspace R-4.6 | Attic Return R- 7.4 |
| Location and R-value | Unconditioned Basement R-5.0 | Unconditioned Basement R-4.6 | Unconditioned Basement R-4.6 | All Unconditioned Space Supply R-7.4 |
| Location and R-value | All Conditioned Space R-0.0 | All Conditioned Space R-4.4 | All Conditioned Space R-4.4 | All Unconditioned Space Return R-6.8 |
| Location and R-value | Attic Exposed R-5.0 | Attic Exposed R-4.6 | Attic Exposed R-4.7 | n/a |
| **Duct Leakage** | | | | |
| CFM25 to CFM25/100 ft2 Conditioned Floor Area | No observable leakage | 478 CFM25 | 17.3 CFM25/100 $ft^2$ | 17.7 CFM25/100 ft2 |

Table 4-6 addresses heating systems. As shown, the average of homeowners' preferred thermostat settings during the heating season is the same as the current UDRH input—68° Fahrenheit. No 2011 baseline homes have a kerosene heating system or an electric air-source heat pump heating system. The average AFUEs of oil, natural gas and propane heating systems are all higher in 2011 baseline homes than in 2001 baseline homes and higher than current UDRH inputs. Only one 2011 baseline home has a ground source heat pump (GSHP) heating system—an ENERGY STAR-qualified system. There is currently no GSHP UDRH input—it is assumed that the homeowner would have installed the same GSHP.

**Table 4-6: Heating Systems**

| Home Feature | Pre 2011 Baseline UDRH MEC 95 | 2001 Baseline | Current UDRH | Baseline Preliminary Estimated UDRH Input |
|---|---|---|---|---|
| **Heating Setpoint** | | | | |
| **Heating Setpoint: ° F** | 68° F | 68° F | 68° F | Preferred Temperature 68° F |
| **Heating System Efficiency:** | | | | |
| **Oil AFUE** | 81.0 AFUE | 82.4 AFUE [e] | 83.3 AFUE | 84.5 AFUE |
| **Kerosene AFUE** | 81.0 AFUE | 82.4 AFUE [e] | 83.3 AFUE | No kerosene systems in homes |
| **Natural Gas AFUE** | 81.0 AFUE | 87.3 AFUE | 90.0 AFUE | 92.4 AFUE |
| **Propane AFUE** | 81.0 AFUE | 87.4 AFUE | 87.1 AFUE | 92.1 AFUE |
| **Heating Electric AirSourceHeatPump** | | | | |
| **Heating Electric Air Source Heat Pump: HSPF** | 6.8 HSPF | 6.8 HSPF | 7.7 HSPF | No 2011 Baseline Homes |
| **Ground Source Heat Pump** | | | | |
| Ground Source Heat Pump: HSPF | Same as ASHP 6.8 HSPF | Same as ASHP 6.8 HSPF | No UDRH Input: Assume Customer would have Installed the same GSHP | One 2011 Baseline Home ENERGY STAR GSHP (COP 5.1) 17.4 HSPF |

[e] From 2001 Baseline Study: RLW recommends updating the efficiencies of oil and kerosene systems to 82.4 AFUE and that of gas and propane systems to 87.3 and 87.4, respectively.[19]

[19] Ibid, p. 37.

Table 4-7 addresses cooling systems. As shown, owners of 2011 baseline homes have a slightly lower preferred thermostat setting for cooling than the current UDRH input. In both the 2001 and 2011 baseline studies, the average Seasonal Energy Efficiency Ratio (SEER) of central cooling systems is just slightly higher than the federal minimum efficiency standard in effect at the time of the study.

**Table 4-7: Cooling Systems**

| Home Feature | Pre 2011 Baseline UDRH MEC 95 | 2001 Baseline | Current UDRH | Baseline Preliminary Estimated UDRH Input |
|---|---|---|---|---|
| **Cooling Setpoint:** | | | | |
| **Cooling Setpoint: ° F** | 75° F | 75° F | 75° F | Preferred Temperature 73° F |
| **Cooling System Efficiency:** | | | | |
| **Cooling System Efficiency: SEER** | 10 SEER | 10.3 SEER | 13.0 SEER | 13.4 SEER |

Table 4-8 on the following page addresses water heating systems. As shown, only one 2011 baseline home had tank wrap insulation—an R-10 tank wrap on a conventional natural gas water heater. There is no UDRH input for water heater insulation, the UDRH or reference home value is the same as the as-built home. There are UDRH inputs for electric, oil, natural gas and propane conventional stand-alone tank water heaters. The average Energy Factor for electric conventional water heaters in 2011 baseline homes is higher than in 2001 baseline homes and the same as the current UDRH input; the average recovery efficiency has not changed; the average tank size is two gallons larger in 2011 baseline homes than in 2001 baseline homes and the current UDRH input. 2011 Baseline Study average Energy Factors and recovery efficiencies for oil, natural gas and propane conventional water heaters are higher than 2001 baseline averages and higher than current UDRH inputs. Differences in average tank size vary: in some cases average tank size in 2011 baseline homes is higher and in some cases lower. 2011 Baseline Study average Energy Factors and recovery efficiencies for oil, natural gas and propane integrated (indirect with tank) water heating systems are higher than 2001 baseline averages and higher than current UDRH inputs; average tank size is the same or larger in 2011 baseline homes. There are no UDRH inputs for instantaneous water heaters—reported water heating savings are deemed savings from the Program Savings Documentation (PSD) manual.

### Table 4-8: Water Heating Systems

| Home Feature | Pre 2011 Baseline UDRH MEC 95 | 2001 Baseline | Current UDRH | Baseline Preliminary Estimated UDRH Input |
|---|---|---|---|---|
| **Water Heating System Insulation** | | | | |
| Water Heating System Insulation | No Extra Tank Insulation for all Fuels | Electric = R-4.0 Oil = R-0.3 Gas = R-2.4 | Reference home (UDRH) same as the as-built home. | Tank wrap reported on only one water heater; R-10 on conventional natural gas tank. |
| **Water Heating** | | | | |
| **Electric Conventional Energy Factor** | .86 EF | .86 EF | .90 EF | .90 EF |
| **Recovery Efficiency** | .98% RE | .98% RE | 98% RE | 98% RE |
| **Gallons** | 50 Gallons | 54 Gallons | 54 Gallons | 56 Gallons |
| **Oil Conventional Energy Factor** | .56 EF | .56 EF | .61 EF | .63 EF |
| **Recovery Efficiency** | 76% RE | 77% RE | 77% RE | 80% RE |
| **Gallons** | 50 Gallons | 49 Gallons | 49 Gallons | 32 Gallons |
| **Oil Integrated (Indirect with tank) Energy Factor** | | | .69 EF | .79 EF |
| **Recovery Efficiency** | | | 77% RE | 80% RE |
| **Gallons** | | | 49 Gallons | 49 Gallons |
| **Natural Gas Conventional Energy Factor** | .56 EF | .56 EF | .58 EF | .62 EF |
| **Recovery Efficiency** | 76% RE | 73% RE | 73% RE | 79% RE |
| **Gallons** | 50 Gallons | 46 Gallons | 46 Gallons | 48 Gallons |
| **Natural Gas Integrated (Indirect with tank) Energy Factor** | | | .75 EF | .87 EF |
| **Recovery Efficiency** | | | 73% RE | 79% RE |
| **Gallons** | | | 46 Gallons | 50 Gallons |
| **Natural Gas Instantaneous Energy Factor** | | | Deemed Savings from PSD [d] Calculated Outside UDRH | .92 EF |
| **Recovery Efficiency** | | | | 93% RE |
| **Propane Conventional Energy Factor** | .56 EF | .56 EF | .56 EF | .63 EF |
| **Recovery Efficiency** | .76 RE | .76 RE | 76% RE | 80% RE |
| **Gallons** | 50 Gallons | 50 Gallons | 50 Gallons | 44 Gallons* |
| **Propane Integrated (Indirect with tank) Energy Factor** | | | .56 EF | .88 EF |
| **Recovery Efficiency** | | | 76% RE | 80% RE |
| **Gallons** | | | 50 gallons | 65 Gallons |
| **Propane Instantaneous Energy Factor** | | | Deemed Savings from PSD Calculated Outside UDRH | .86 EF |
| **Recovery Efficiency** | | | | 88% RE |

[d] The Program Savings Documentation manual (PSD).

Table 4-9 addresses lighting. There are no UDRH lighting inputs—the UDRH or reference home has the same lighting as the as-built home. However, comparing the results of the 2001 and 2011 baseline studies clearly shows an increase in the penetration of energy-efficient lighting.

**Table 4-9: Lighting**

| Home Feature | Pre 2011 Baseline UDRH MEC 95 | 2001 Baseline | Current UDRH | Baseline Preliminary Estimated UDRH Input |
|---|---|---|---|---|
| **Lighting** [f] | | | | |
| Incandescent | # of Permanent Incandescent = 8 | # of Permanent Incandescent Bulbs = 56 | Reference home (UDRH) same as the as-built home. | # of Total Fixtures = 47.2 |
| Fluorescent | # of Permanent Fluorescent = 0 | # of Permanent Fluorescent Bulbs = 1 | | # of Energy-Efficient Fixtures = 4.4 |

[f] 2011 study counted fixtures, not bulbs. Energy-efficient fixtures include hard-wired fixtures with screw-in CFL bulbs, pin-based CFL bulbs, LED bulbs, or fluorescent tubes.

# 5 General Characteristics of Inspected Homes

The most popular style of the homes inspected is colonial (33% of inspected homes) followed by cape (22%), ranch (20%), and contemporary (14%). With the exception of one duplex, all of the homes are detached single-family homes. All homes except for one are year-round primary residences. The smallest home inspected is 880 square feet and the largest is 7,090 square feet (Figure 5-1). The average conditioned floor area[20] for all homes is 2,758 square feet and the median is 2,486 square feet. The average custom home is 3,036 square feet and the average spec home is 2,628 square feet. The majority of homes (55%) are two stories; 38% are one to one and one-half stories and 7% are two and one-half to three stories. Figure 5-2 shows examples of the different size homes inspected.

**Figure 5-1: Conditioned Floor Area**

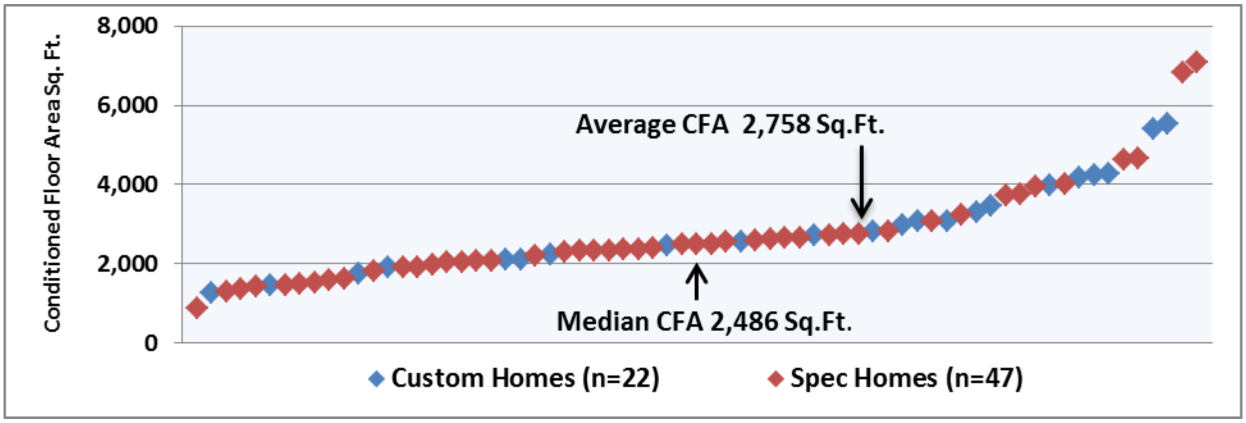



**Figure 5-2: Examples of Inspected Homes**

[20] 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

# 6 Homeowner On-Site Survey

The 69 homeowners were asked to complete a brief survey during the audits. Survey topics included how the homes were purchased, if energy efficiency was discussed between the homeowner and the real estate agent or builder, how important energy efficiency was in the decision to purchase the home, homeowners' perception of the energy efficiency of their homes, and who specified various components in the home. The survey also asked if homeowners had ever participated in any utility-sponsored energy efficiency programs. A total of five homeowners (including two owner-builders) report having previously participated in a utility-sponsored energy efficiency program, including one or more of the following: weatherization programs, appliance rebate programs, and Home Energy Solutions. Homeowners who acted as the builder for their own home (four of the 69 homeowners) are either excluded from analyses that do not apply to them due to their role as builder, or are examined separately from the rest of the homeowners in this section. (Appendix H On-site Homeowner Survey Instrument)

The results of the home owner survey suggest many home buyers may start out wanting an energy-efficient home, but do not know what to look for or ask about to ensure they get an energy-efficient home. It isn't until after they are living in their new home that they find out it may not be as energy efficient as they expected or wanted. Also, many owners who said they specified components of their new home did not specify energy-efficient or ENERGY STAR-qualified options, suggesting energy efficiency may not have been as important as they indicated when they rated the importance of getting an energy-efficient home. The following examples are based on 65 of the 69 inspected homes; not included are three new homes and one gut rehab home where the owner was also the builder. Discussion of the actual energy efficiency of homes is based on HERS ratings—the lower the HERS rating, the more energy efficient the home.

The homes of owners who said getting an energy-efficient home was important in their decision to buy or build their home have an average HERS rating of 81, which is only slightly more energy efficient than the average HERS rating of 82 for all inspected homes. Roughly two-thirds of owners (42 of 65) rated the importance of getting an energy-efficient home 8 or higher on a scale of 0 to 10, but only half of these owners think their home is much more or somewhat more energy efficient than other new homes. These 42 homes include the most energy-efficient home inspected (HERS 62) and two of the three least energy-efficient homes inspected (HERS 102). Almost half (43%) of these 42 homes have HERS ratings that are higher (less energy efficient) than the average HERS rating for all inspected homes. There are several plausible reasons why homes of owners who said getting an energy-efficient home was important are not that energy efficient. Many home buyers do not have the language or understanding to know what to request when buying or building a home. Many home buyers do not have the knowledge to accurately assess the energy efficiency of their home. They may have no idea whether or not they have 2 x 6 framing let alone the importance of sealing and insulation. Or, they may think any home with 2 x 6 framing is energy efficient. They may simply take the builder's word that a home is energy efficient. They may start out wanting the most energy-efficient options, but when budget limitations come into play the first things to go are 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.

In most cases, owners who said they specified components of their home important to efficiency said they did not specify an energy-efficient or ENERGY STAR-labeled component, which suggests there is a need for additional consumer education. Of the 65 owners who did not build their own home, 77% (or 50 owners) said they specified aspects of one or more of the following components of their home: heating system, cooling system, water heater, windows, kitchen appliances, or lighting. Seventy percent of these 50 owners (35 owners) also ranked the importance of getting an energy-efficient home in their decision to build or purchase their home an 8, 9 or 10 on a scale of 0 (not important) to 10 (very important). However, when it came to specifying components of their home, it appears energy efficiency was not really a high priority for many of these owners. For most components, fewer than half of the owners who specified the component specified an energy-efficient or ENERGY STAR-qualified option: 8 of 18 (44%) who specified aspects of the heating system, 4 of 16 (25%) who specified aspects of the cooling system, 7 of 19 (37%) who specified aspects of the water heater, and 11 of 37 (30%) who specified aspects of the lighting. Owners were more likely to specify energy-efficient or ENERGY STAR-qualified windows (17 of 22 owners or 77%) and kitchen appliances (32 of 49 owners or 65%). Some owners indicated only that they specified a component of their home, without indicating what aspects of that component they specified. Owners who did identify the aspects of the components they specified, but did not specify energy-efficient or ENERGY STAR-labeled components, said they specified one or more of the following: the heating or water heating fuel; the type of heating, cooling or water heating system; whether or not to install central air conditioning; appliance fuel (gas or electric), style, brand, and/or color; the style of lighting fixtures.

## *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; this includes three new homes where the owner was the builder, and one gut rehab where the owner was the builder. 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. Just over two-thirds (68%) of the homes are spec homes, and just under one-third (32%) 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 (38%), followed by purchasing land

and working with an architect and/or builder to design and build the home (19%), and purchasing a finished home (16%). The majority of homeowners who purchased a lot from a builder and selected one of several house plans offered (23 out of 26) reported that they were able to select from various available upgrade options; one homeowner reported not being able to select from various available upgrade options, and two left the question blank. One out of the four homeowners who purchased a home that was under construction was able to select from various available upgrade options.

**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 | 26 | 38% |
| Purchased a finished home | 11 | 16% |
| Other* | 6 | 9% |
| Purchased a home that was under construction | 4 | 6% |
| Subtotal Spec Homes: | 47 | 68% |
| **Custom Homes** | | |
| Purchased land and worked with an architect and/or builder to design and build the home | 13 | 19% |
| Other** | 5 | 7% |
| I am the owner and builder | 3 | 4% |
| Had a house plan and a lot and hired a contractor/builder to build the home | 1 | 1% |
| Subtotal Custom Homes: | 22 | 32% |

* Three spec homes are modular homes built on land purchased or already owned by the homeowner; one is a modular home built by an owner who tore down an existing home; one is a home that was marketed on realtor sites even though the homeowner reported to have built the home with a house plan; one is a home built for a homeowner who asked a builder to build a house he saw in the area, but did not dictate any of the specs.

** Two custom homes are homes rebuilt on existing foundations by owners following a natural disaster or fire; the remaining three are gut rehabs. The owner was also the builder for one of the three gut rehabs.

## 6.2 Discussed Energy Efficiency with Builder or Sales Agent

Fewer than one-half (40%) of homeowners say their builder or sales agent talked to them about energy efficiency or the benefits of energy-efficient windows, heating and cooling equipment, insulation, etc. Just over one-half (34 or 52%) of homeowners say they asked their builder or the sales agent about energy efficiency, which suggest there is a need for additional consumer education to encourage home buyers to ask builders and real estate agents about energy efficiency. Table 6-2 shows that only one-third (33%) of homeowners who say that their builder or sales agent did not talk to them about energy efficiency, or they do not remember, say they asked about energy efficiency. Most homeowners (81%) who say their builder or sales agent talked to them about energy efficiency also say they asked about energy efficiency. In all, 39 (26 plus 13) or 60% of homeowners had some sort of discussion about energy efficiency with their builder or the sales agent.

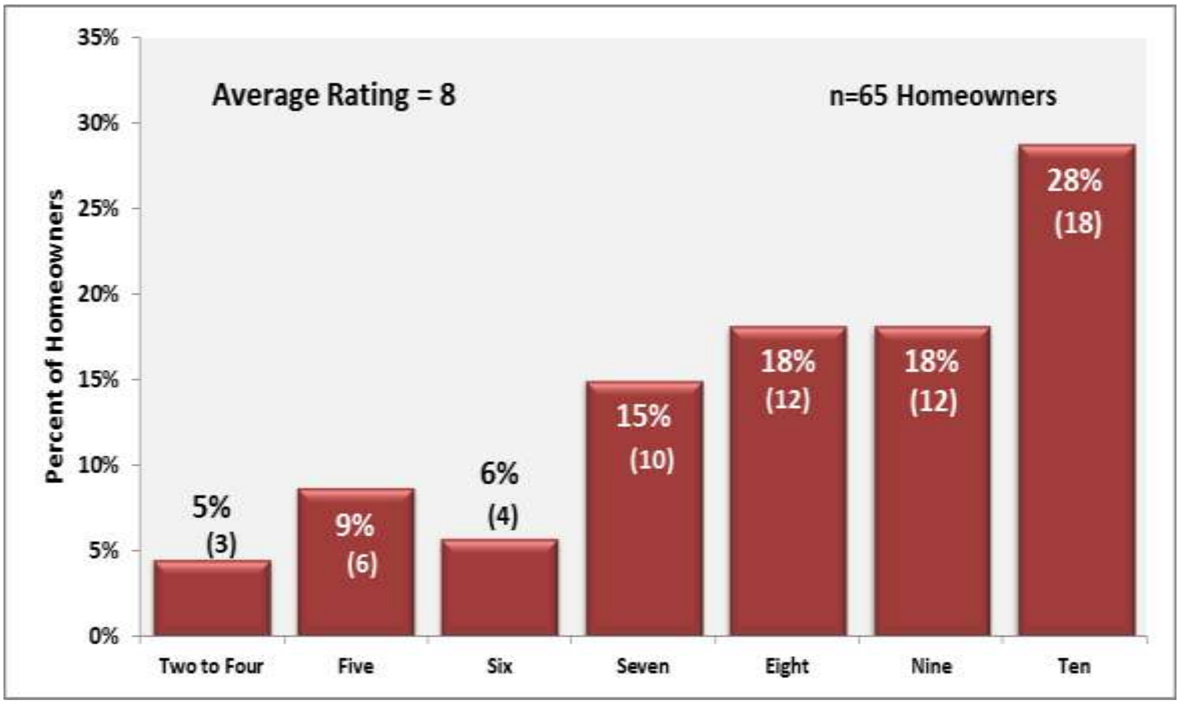
**Table 6-2: Homeowners Who Discussed Energy Efficiency**

| 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 Did NOT Talk About Energy Efficiency or Homeowner Does Not Remember | 39 (60%) | 13 | 33% |
| Builder or Sales Agent Talked About Energy Efficiency (Includes homeowner/builders) | 26 (40%) | 21 | 81% |
| Total Homeowners: | 65 | 34 | 52% |

## 6.3 Importance of Getting an Energy-Efficient Home

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 eight. Figure 6-1 shows that very few homeowners rated energy efficiency below five, and almost two-thirds (64%) rated energy efficiency eight or higher. Of the four homeowners who acted as the builder for their own home (not depicted in Figure 6-1), two provided a rating of ten, one provided a rating of nine, and one provided a rating of eight.

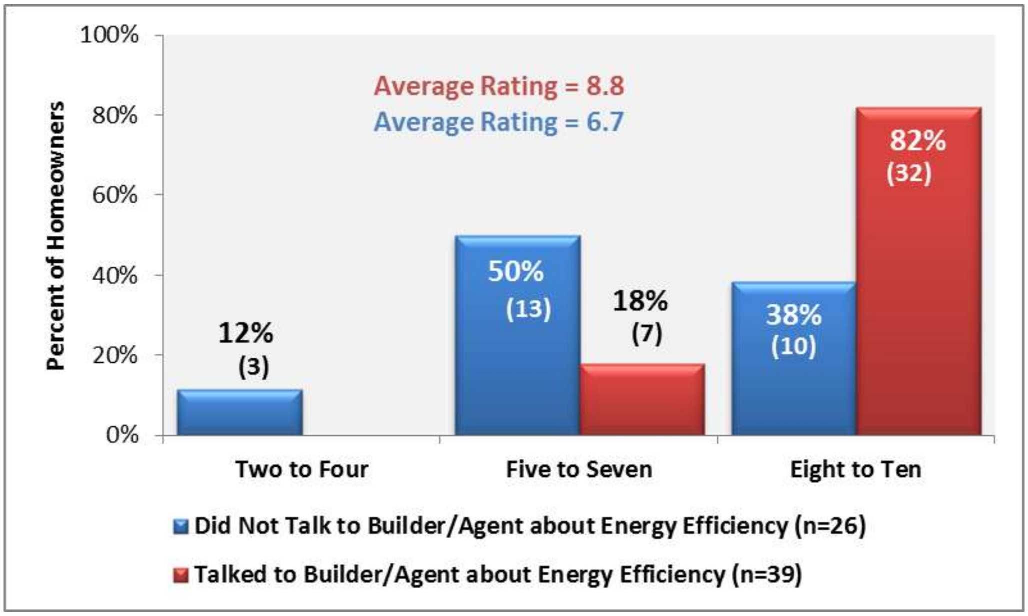
**Figure 6-1: Importance of Getting an Energy-Efficient Home***




*Number of homeowners in parentheses.

Figure 6-2 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 one-half (39 or 60%) 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 8.8; the average rating for homeowners who said they did not talk to their builder/sales agent about energy efficiency is 6.7. Despite not having talked to the builder or sales agent about energy efficiency, nearly two out of five homeowners (38%) still assigned a high rating (from eight to ten) to the importance of getting an energy-efficient home.

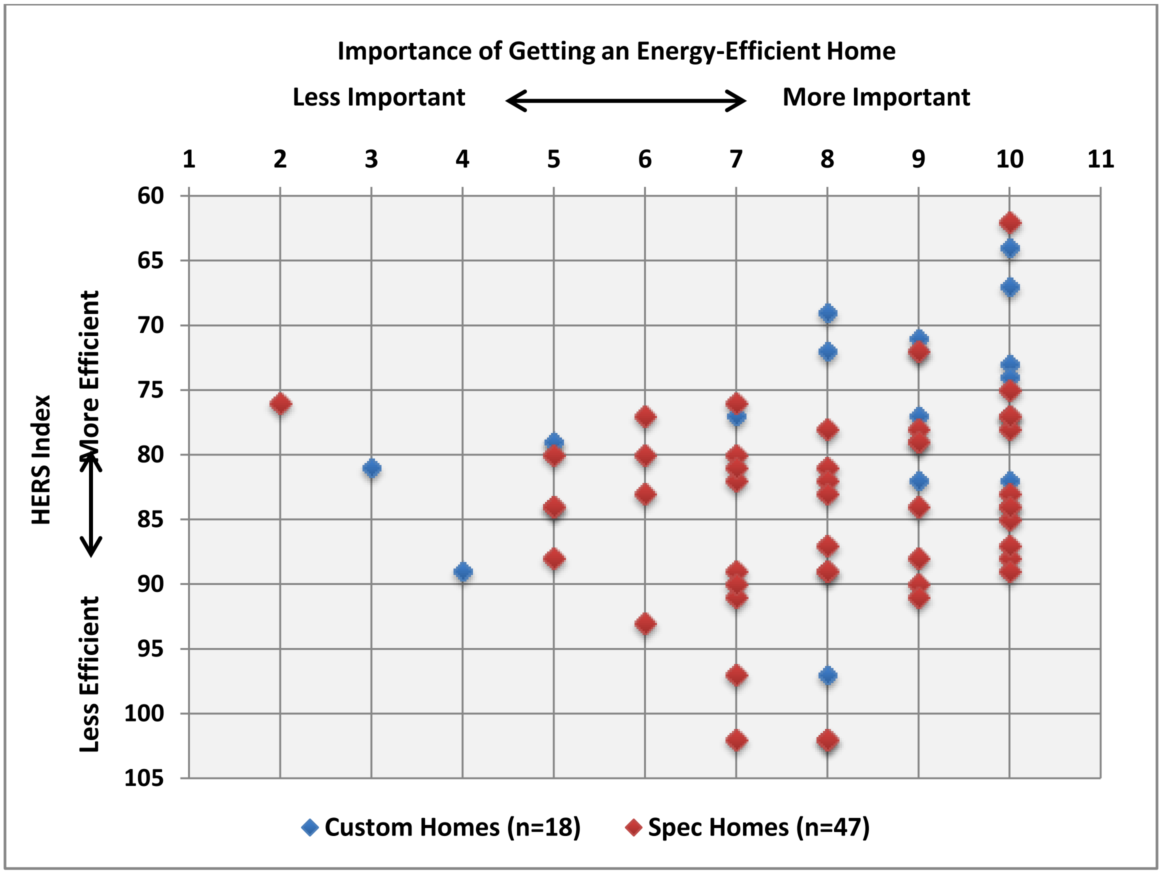
**Figure 6-2: Importance of Getting an Energy-Efficient Home by Talked to Builder/Agent about Energy Efficiency***




*Number of homeowners in parentheses.

Figure 6-3 displays the HERS ratings achieved by how homeowners rated the importance of getting an energy-efficient home. As shown, it seems clear that features other than energy efficiency are driving new construction—regardless of how "important" homeowners say getting an energy-efficient home was in their decision to buy or build their home. The four homeowners who acted as the builder for their own home and are not depicted in Figure 6-3 have HERS ratings of 74, 76, 85, and 91, respectively.

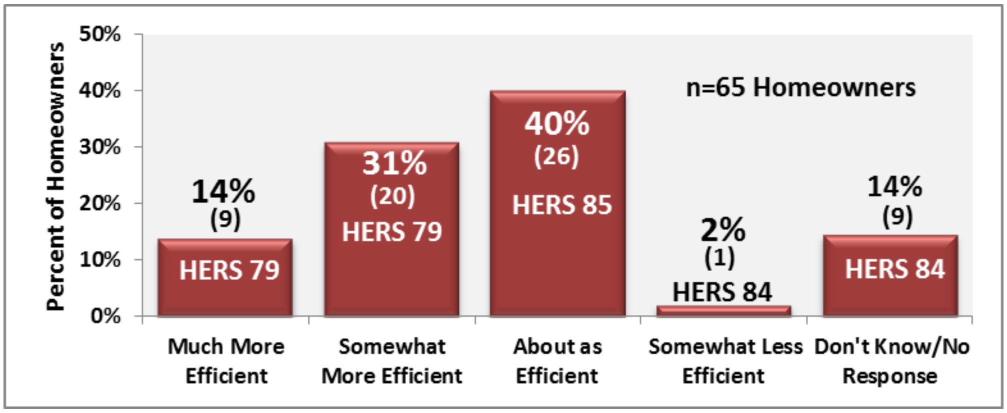
**Figure 6-3: Importance of getting an Energy-Efficient Home by HERS Index**



## 6.4 Perception of New Home's Energy Efficiency

Figure 6-4 shows that most homeowners think their home is about as energy efficient as most other new homes (40%) or somewhat more energy efficient (31%). Homeowners who perceive their home to be more energy efficient than other new homes generally do have more efficient homes—the average HERS rating for homeowners who think their home is more efficient than other new homes is 79, as compared to an average HERS rating of 85 for those who think their home is about as efficient as other new homes. Figure 6-4 excludes the four homeowners who acted as the builder for their own home, the majority of whom think their homes are somewhat more efficient than other new homes.

**Figure 6-4: Homeowner Perception of Energy Efficiency of Home and Average HERS Index***



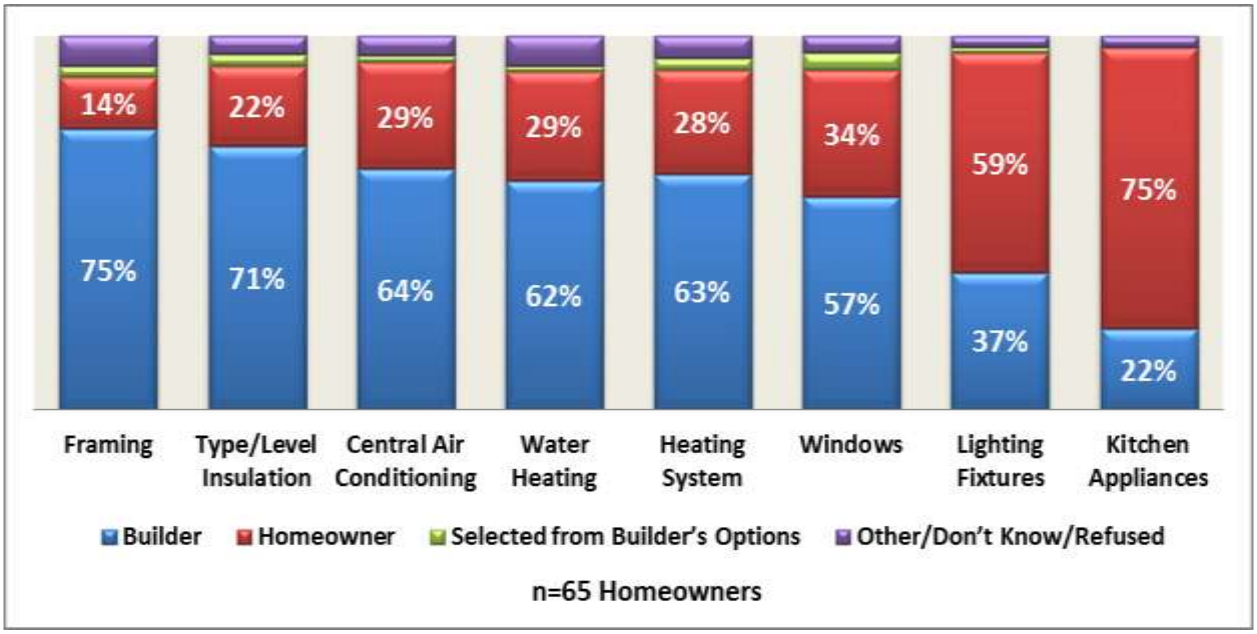

*Number of homeowners in parentheses.

Homeowners were asked to explain why they think their home is more, about the same, or less energy efficient than most other new homes. Those who believe their home is about as efficient as other new homes frequently mentioned the builder. Homeowners who believe their home is somewhat more efficient than other new homes cited specific materials, construction practices and/or high-efficiency mechanical equipment. The homeowner who said their new home is less efficient than other new homes reported feeling air leaks in the home.

## 6.5 Who Specified Energy-Efficiency Related Components

Homeowners were asked to indicate who specified several energy-efficiency related components in their homes. Figure 6-5 shows that builders are most likely to specify framing, insulation, heating and cooling equipment, water heaters, and windows, while homeowners are most likely to specify kitchen appliances and lighting fixtures. Nearly one out of five of the 38 homeowners who said they selected their lighting fixtures commented on specifying the style, highlighting the importance of style to this particular building component. The four homeowners who acted as the builder for their own home and are not depicted in Figure 6-5 generally specified all components in their homes.

**Figure 6-5: Who Specified Building Components***




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

# 7 Building Envelope

The on-site inspections included collecting information on walls, ceilings, floors, windows, doors, foundation walls, slabs, and rim/band joists on the thermal boundary of homes.

## 7.1 Wall Insulation

Auditors recorded insulation information for all walls on the thermal boundary of homes. This includes conditioned/ambient walls, conditioned/garage walls, unconditioned basement/ambient walls, conditioned/attic walls, and conditioned/unconditioned basement walls. Auditors described how each wall was framed and the type, R-value and grade of the insulation installed.

Fiberglass batt insulation is clearly dominant; only four homes had something other than or in combination with fiberglass batts.[21] Table 7-1, shows average insulation levels range from R-18 to R-19 depending on the wall type. All but two homes have 16 inch on center stud spacing and the majority of all types of walls are 2x6 stud construction. Insulation was least likely to be observable in conditioned/ambient walls (no homes) and most likely to be observable in conditioned/attic walls (5 out of 7 homes). Auditors assigned a Grade I rating, the best rating, to insulation installation in only one home (the unconditioned basement/ambient walls in a spec home) and Grade III, the worse rating, in 8 out of 69 homes with conditioned ambient walls, 3 out of 25 homes with insulated unconditioned basement/ambient walls, 8 out of 48 homes with conditioned/garage walls and 2 out of 7 homes with conditioned/attic walls.

**Table 7-1: Characteristics of Each Wall Type**

| Wall Location→ | Conditioned/ Ambient (n=69) | Conditioned/ Garage (n=48) | Unconditioned Basement/ Ambient (n=27) | Conditioned/ Attic (n=7) | Conditioned/ Unconditioned Basement (n=7) |
|---|---|---|---|---|---|
| Average R-value | R-19 | R-19 | R-18 | R-18 | R18 |
| **Framing** | | | | | |
| 2x4 16" On Center | 4 | 3 | 1 | 2 | 1 |
| 2x6 16" On Center | 60 (87%) | 43 (90%) | 25 (93%) | 5 (71%) | 6 (86%) |
| 2x6 24" On Center | 2 | 1 | 0 | 0 | 0 |
| 2x10 16" On Center | 1 | 1 | 1 | 0 | 0 |
| Mix 2x4 & 2x6 16" On Center | 2 | 0 | 0 | 0 | 0 |
| **Insulation Visibility, Installation Grade and Percent Fiberglass Batt** | | | | | |
| Insulation Visible | 0 | 2 | 8 | 5 | 1 |
| Grade I Installation | 0 | 0 | 1 | 0 | 0 |
| Grade II Installation | 61 (88%) | 40 (83%) | 21 (84%) | 5 (71%) | 7 (100%) |
| Grade III Installation | 8 | 8 | 3 | 2 | 0 |
| Fiberglass Batt | 67 (97%) | 47 (98%) | 22 (81%) | 7 (100%) | 7 (100%) |

[21] One spec home had Icynene in conditioned/ambient and conditioned/garage walls; one custom home had fiberglass batts with R-7 thermal wrap in some conditioned/ambient walls and blown in fiberglass in other conditioned/ambient walls; one spec home had unconditioned basement/ambient walls insulated with rigid foam and another had fiberglass batts with thermal wrap.

### *7.1.1 Conditioned/Ambient Walls*

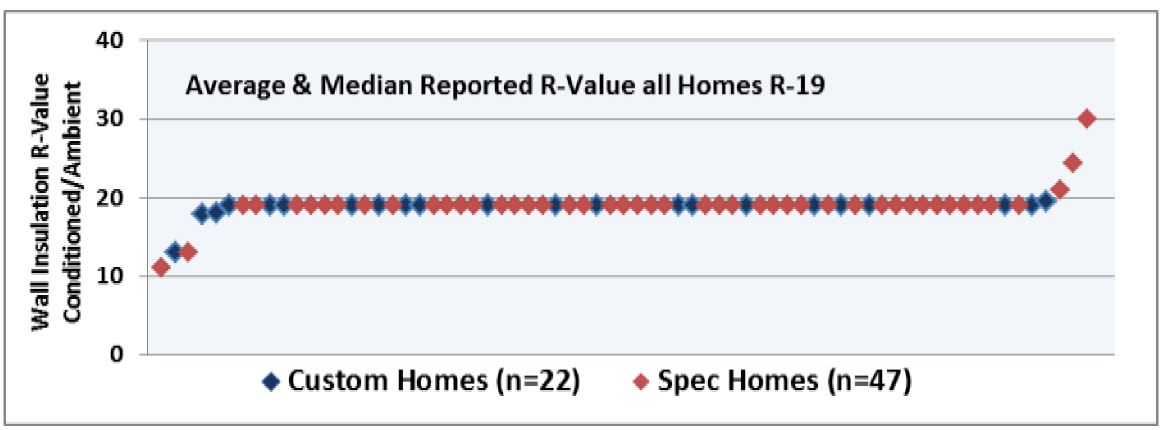
Because of their greater importance in overall home energy efficiency, the remainder of this section focuses on the efficiency of conditioned/ambient walls. The 2006 IECC prescriptive requirement for wood framed wall insulation is R-19 or R-13 cavity insulation plus R-5 insulated sheathing; the 2009 IECC requirement is R-20 or R-13 cavity insulation plus R-5 insulated sheathing. Table 7-2 shows that almost all homes, 93% or 64 of 69 homes have R-19 or higher conditioned/ambient wall insulation; 5 homes have less than R-19—3 custom homes and 2 spec homes. Only 3 homes, all custom homes, have R-20 or higher conditioned/ambient wall insulation.

**Table 7-2: Conditioned/Ambient Wall Statistics**

| Conditioned/Ambient Exterior Wall Insulation Levels and R-value Statistics | All Homes (n=69) |
|---|---|
| **Comparison with 2006 IECC R-19 Requirement** | |
| Less than R-19 | 5 (7%) |
| = R-19 | 60 (87%) |
| More than R-19 | 4 (6%) |
| **Comparison with 2009 IECC R-20 requirement** | |
| Less than R-20 | 66 (96%) |
| = R-20 | 0 |
| More than R-20 | 3 (4%) |
| **R-value Statistics** | |
| Minimum R-value | 11 |
| Maximum R-value | 30 |
| Average R-value | 19 |
| Median R-value | 19 |

Figure 7-1 graphs recorded R-values in conditioned/ambient walls for all 69 inspected homes.

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



## 7.2 Ceiling Insulation

Auditors reported data for attic insulation installations where the insulation covered the joists, attic insulation where the insulation did not cover the joists, and cathedral ceilings.[22] The 2006 and 2009 IECC prescriptive ceiling insulation requirement is R-38 with up to 500 square feet of cathedral ceiling area allowed to be R-30. Table 7-3 shows 30% of inspected homes (32% of custom and 28% of spec homes) have at least R-38 insulation in flat ceilings. Only 7 of the 20 homes with cathedral ceilings (35%) have R-38 or higher insulation. However, the code allows 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 in this allowance allows an additional eight homes meet the standards for cathedral ceilings, resulting in an overall 75% of homes with cathedral ceilings (83% of custom and 71% of spec homes) meeting code requirements. Flat ceiling insulation levels range from R-19 to R-60; the average is R-34 and the median is R-30. Cathedral ceiling insulation levels range from R-19 to R-48; the average is R-32 and the median is R-30.

**Table 7-3: Ceiling Insulation Statistics**

| Ceiling Insulation Levels and R-value Statistics | Flat Ceilings All Homes (n=68) | Cathedral Ceilings All Homes (n=20) |
|---|---|---|
| **Comparison with 2006 & 2009 IECC R-38 in Flat Ceilings and R-30 in not more than 500 Square Feet of Cathedral Ceiling Area Requirements** | | |
| **Less than R-38 Flat/More than 500 ft$^2$ Cathedral < R-38** | 48 (71%) | 5 (25%) |
| **R-38 Flat/Not More than 500 ft$^2$ Cathedral < R-38** | 12 (18%) | 10 (50%) |
| **More than R-38 Flat/Cathedral more than R-30 in 500 ft$^2$ or > R-38** | 8 (12%) | 5 (25%) |
| **R-value Statistics** | | |
| **Minimum R-value** | 19 | 19 |
| **Maximum R-value** | 60 | 48 |
| **Average R-value** | **34** | **32** |
| **Median R-value** | 30 | 30 |

The most energy-efficient practice for flat ceilings is to cover joists with insulation; 23 of the 68 inspected homes (34%) have at least some flat ceiling area where the insulation covers the joists. Twenty of the inspected homes have cathedral ceilings.

Table 7-4 shows the characteristics of the ceilings inspected. Average R-values range from R-31 for flat ceilings with joists not covered to R-40 for flat ceilings with joists covered with insulation. The most common framing is 2x10 16 inch on center, followed by truss and 2x8 16 inch on center framing. Together, 2x10 and 2x8 16 inch on center and truss framing account for over 80% of flat and cathedral ceilings. Auditors were able to visibly inspect most flat ceiling

[22] In one home, auditors were unable to access the attic without damage to the scuttle hole hatch lid. When unable to access the attic, auditors attempted to get information from specs or from the homeowner. In this case, no specs were available and the homeowner had no idea what was in the attic.

insulation installations: 87% of uncovered flat joist and 91% of covered flat joist ceilings. In contrast, auditors were able to visually inspect the cathedral ceiling insulation in only one home.

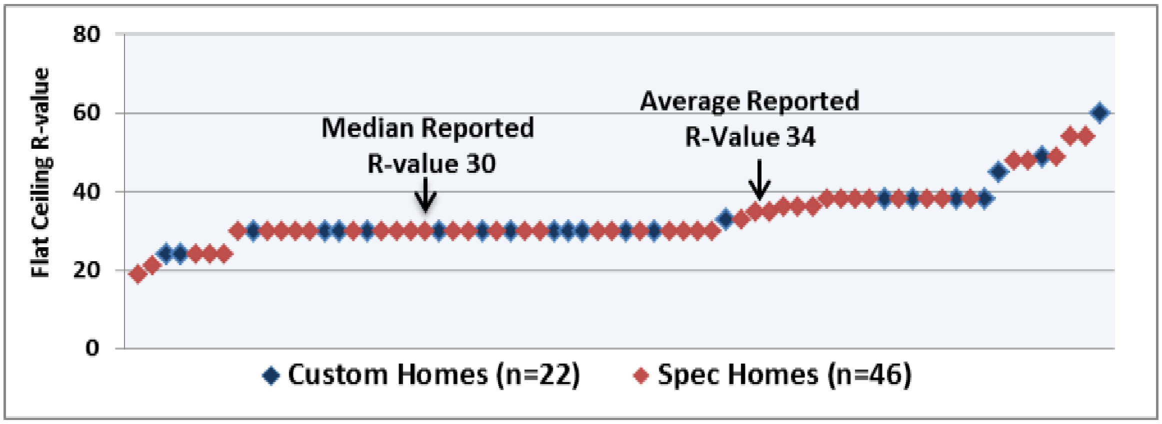
Grade I ceiling insulation installation was reported for eight homes; five homes with flat ceilings insulated with fiberglass batts, one with flat ceilings insulated with cellulose, one with flat ceilings insulated with blown in fiberglass, and one home with flat and cathedral ceilings insulated with fiberglass batts. Fiberglass batt insulation dominates in flat ceilings where the insulation does not cover the joists (85%) and cathedral ceilings (90%). In ceilings where the flat joists are covered, the most common type of insulation is cellulose (43%), followed by fiberglass batts (39%).

**Table 7-4: Ceiling Characteristics**

| Ceiling Type → | Flat Joists Not Covered (n=47) | Flat Joists Covered (n=23) | Cathedral (n=20) |
|---|---|---|---|
| **Average Reported R-value** | 31 | 40 | 32 |
| **Framing** | | | |
| **2x6 16" On Center** | 3 | 4 | 3 |
| **2x6 24" On Center** | 1 | 0 | 0 |
| **2x8 16" On Center** | 7 (15%) | 2 (9%) | 3 (20%) |
| **2x10 16" On Center** | 25 (53%) | 11 (48%) | 9 (45%) |
| **2x12 16" On Center** | 1 | 0 | 0 |
| **2x12 24" On Center** | 1 | 0 | 0 |
| **2x10x16 I-Joists** | 1 | 0 | 0 |
| **Truss** | 8 (9%) | 6 (26%) | 5 (25%) |
| **Insulation Visibility and Installation Grade** | | | |
| **Insulation Visible** | 40 (87%) | 21 (91%) | 1 (5%) |
| **Grade 1 Installation** | 5 | 3 | 1 |
| **Grade 2 Installation** | 37 (79%) | 14 (61%) | 16 (80%) |
| **Grade 3 Installation** | 5 | 6 | 3 |
| **Type of Insulation** | | | |
| **Fiberglass Batt Insulation** | 40 (85%) | 9 (39%) | 18 (90%) |
| **Blown-in Fiberglass** | 5 | 3 | 0 |
| **Cellulous** | 2 | 10 (43%) | 2 |
| **Fiberglass Batts & Cellulose** | 0 | 1 | 0 |

Figure 7-2 graphs the individual recorded flat ceiling insulation R-values for all 68 inspected homes with reported ceiling insulation information.

**Figure 7-2: Recorded Flat Ceiling Insulation R-values**




### *7.2.1 Who Specified Framing and Insulation*

The on-site homeowner survey asked who specified the framing and insulation. The choices were:

- I specified
- 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." Homeowners were not specifically asked about wall insulation. Because every home has exterior wall insulation, the survey responses are discussed in this section.

#### *Framing*

Twelve homeowners say they specified the type of framing for their home; ten of these homeowners also say they specified the insulation. All twelve homes where the owners say they specified the framing have 2x6 16 inch on center framing.

Table 7-5 shows that owners of custom homes were more than eleven times as likely as owners of spec homes to say they specified framing (10 out of 22 owners of custom homes versus 2 out of 47 owners of spec homes)—45% of owners of custom homes compared to only 4% of owners of spec homes. Owners of spec homes were more likely than owners of custom homes to say the builder specified framing—89% of owners of spec homes compared to 36% of owners of custom homes. These differences are statistically significant at the 90% confidence level.

**Table 7-5: Who Specified Framing**

| Who Specified Framing and 2x6 16 Inch on Center Framing** | All Homes (n=69) | | Custom Homes (n=22) | | Spec Homes (n=47) | |
|---|---|---|---|---|---|---|
| | Number of Homes | Number 2x6 16" o.c. | Number of Homes | Number 2x6 16" o.c. | Number of Homes | Number 2x6 16" o.c. |
| **Owner Specified** | 12 (17%) | 12 | 10 **(45%)*** | 10 | 2 **(4%)*** | 2 |
| **Builder Chose** | 50 (72%) | 45 | 8 **(36%)*** | 8 | 42 **(89%)*** | 37 |
| **Selected from Options Offered by the Builder** | 2 | 2 | 2 | 2 | 0 | n/a |
| **No Response** | 3 | 2 | 1 | 1 | 2 | 1 |
| **Other** | 2 | 1 | 1 | 0 | 1 | 1 |
| **All Homes** | **69** | **62** | **22** | **21** | **47** | **41** |

*Significantly different at the 90% confidence level.
** In this table, two homes with a mix of 2x4 and 2x6 16" on center framing are treated as having 2x6 16" on center framing. In both homes the 2x4 stud wall area is less than 10% of total wall area.

All homes where the owner specified the framing or selected from options offered by the builder have 2x6 16 inch on center framing. Only 5 of the 50 homes where builders chose the framing (all spec homes) do not have 2x6 16 inch on center framing; two of these homes have 2x4 16 inch on center framing, two have 2x6 24 inch on center, and one has 2x10 16 inch on center framing. Three homeowners did not say who specified framing; owners of one custom and one spec home with 2x6 16 inch on center framing and the owner of one spec home with 2x4 16 inch on center framing. The "other" category includes two homes; one is a custom home gut rehab that kept the original 2x4 16 inch on center walls and the other is a modular home with what the owner called "pre-chosen" 2x6 16 inch on center framing.

### *Insulation*

Table 7-6 shows that a majority of homeowners (68%) say the builder chose the type and level of insulation. One-fourth of owners (25% or 17 owners) responded that they specified the insulation—12 owners of custom homes and 5 owners of spec homes. The custom homes include two owner/built homes and two gut rehabs; the spec homes include two modular homes. Of these 17 owners, 7 say they specified only the type of insulation, 4 say they specified only the level, 2 say they specified both the type and level, and 4 did not indicate what they specified. Owners of custom homes were five times as likely as owners of spec homes to say they specified insulation: 12 out of 22 or 55% of owners of custom homes compared to 5 out of 47 or 11% of owners of spec homes. Owners of spec homes are almost twice as likely to say the builder specified the insulation—81% of owners of spec homes compared to 41% of owners of custom homes. These differences are statistically significant at the 90% confidence level.

Table 7-6 also shows that, over all homes, the average R-value is similar (R-19) regardless of who specified the insulation except for the three homes where the owners either did not respond to the question or did not remember who specified the insulation. In these three homes the average insulation level is R-17.

**Table 7-6: Who Specified Insulation**

| Who Specified Insulation and Average Conditioned/Ambient Wall R-Value | All Homes (n=69) | | Custom Homes (n=22) | | Spec Homes (n=47) | |
|---|---|---|---|---|---|---|
| | Number of Homes | Average Wall R-value | Number of Homes | Average Wall R-value | Number of Homes | Average Wall R-value |
| **Owner Specified** | 17 (25%) | R-19 | 12 **(55%)*** | R-19 | 5 **(11%)*** | R-21 |
| **Builder Chose** | 47 (68%) | R-19 | 9 **(41%)*** | R-18 | 38 **(81%)*** | R-19 |
| **Selected from options offered by the builder** | 2 | R-19 | 1 | R-19 | 1 | R-19 |
| **No Response or Did Not Remember** | 3 | R-17 | 0 | n/a | 3 | R-17 |
| **Total** | **69** | **R-19** | **22** | **R-19** | **47** | **R-19** |

*Significantly different at the 90% confidence level.

As reported earlier, 97% or 67 of the 69 inspected homes have fiberglass batt conditioned/ambient wall insulation. In the two homes with something other than only fiberglass batts, the homeowners say that they specified the type of insulation; one home is a spec home with R-25 Icynene insulation and one is a custom home with R-19 fiberglass batts combined with R-7 thermal wrap. Two homeowners (one custom and one spec home) who say the builder chose the insulation say they wanted more insulation than the builder chose. The owner of the spec home commented, “I tried to get a higher rate of insulation, but the builder refused.”

## 7.3 Floor Insulation

Auditors recorded data on floor insulation between conditioned spaces and unconditioned basements, garages, the outside, and crawlspaces. 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. Table 7-7 shows 40% of homes with floors over unconditioned basements, 60% of homes with floors over garages, 55% of homes with floors over outside air, and no homes with floors over crawlspaces have R-30 insulation or the framing cavity is filled and the insulation is at least R-19. Floor insulation levels range from no insulation to R-30 in floors over conditioned basements, garages, and the outside, and from no insulation to R-27 in floors over crawlspaces. Average R-values range from R-16.3 in floors over crawlspaces to R-25.4 in floors over outside air.

**Table 7-7: Floor Insulation Statistics**

| Floor Insulation Levels and R-value Statistics | Conditioned/ Basement (n=57) | Conditioned/ Garage (n=30) | Conditioned/ Outside (n=11) | Conditioned/ Crawlspace (n=4) |
|---|---|---|---|---|
| **Comparison with 2006 & 2009 IECC R-30 or Filled Cavity (min R-19) Standard** | | | | |
| **Less than R-30 or Cavity filled with < R-19** | 34 (60%) | 12 (40%) | 5 (45%) | 4 (100%) |
| **R-30 or Cavity Filled Min R-19** | 23 (40%) | 18 (60%) | 6 (55%) | 0 |
| **More than R-30** | 0 | 0 | 0 | 0 |
| **R-value Statistics** | | | | |
| **Minimum R-value** | 0.0 | 0.0 | 19.0 | 0.0 |
| **Maximum R-value** | 30.0 | 30.0 | 30.0 | 27.0 |
| **Average R-value** | **20.5** | **22.1** | **25.4** | **16.3** |
| **Median R-value** | 19.0 | 24.0 | 24.0 | 19.0 |

Custom homes were more likely than spec homes to meet insulation requirements for floors over unconditioned basement space (50% of custom homes versus 36% of spec homes) and the average R-value of floor insulation over unconditioned basements is higher in custom homes than in spec homes (R-22.6 in custom homes versus R-19.5 in spec homes). However, these differences are not statistically significant.

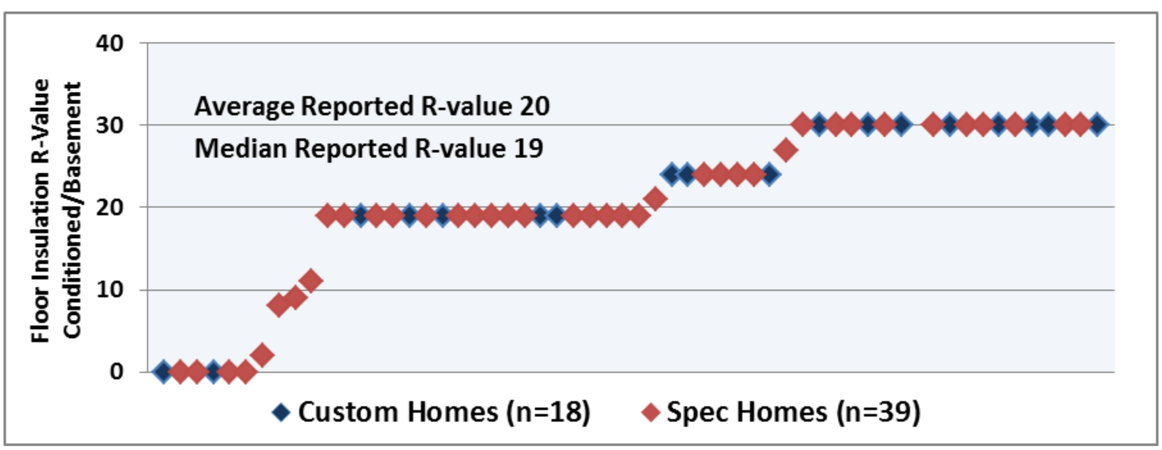
Table 7-8 shows most inspected homes (83% or 57 out of 69 homes) have floors between conditioned space and unconditioned basement space, 30 homes have floors over garages, 11 have floors over outside air, and 4 have floors over crawlspaces. The average level of floor insulation is R-20.5 over unconditioned basements, R-22.1 over garages, R-25.4 over outside air, and R-16.3 over crawlspaces. The most common framing is 2x10 16 inch on center. Auditors were able to visually verify floor insulation or the lack of insulation in 56 of 57 or 98% of the homes with floors over unconditioned basement space, in 13 of 30 or 43% of the homes with floors over garages, in none of the 11 homes with floors over outside air, and in 3 of 4 or 75% of the homes with floors over crawlspaces. While code requires floors over unconditioned basements be insulated, they were not insulated in six homes; in all other homes the floors were insulated with fiberglass batts. Six homes received a Grade I for floor insulation installation; two custom homes and one spec home received Grade I ratings for conditioned/basement floor insulation and three spec homes received Grade I ratings for both conditioned/basement and conditioned/garage floor insulation.

**Table 7-8: Floor Characteristics**

| Floor Location → | Conditioned/ Basement (n=57) | Conditioned/ Garage (N=30) | Conditioned/ Outside (n=11) | Conditioned/ Crawlspace (n=4) |
|---|---|---|---|---|
| Average Reported R-value | 20.5 | 22.1 | 25.4 | 16.3 |
| **Framing** | | | | |
| 2 x 6 x 16" On Center | 1 | 0 | 0 | 0 |
| 2 x 8 x 12" On Center | 0 | 0 | 0 | 1 |
| 2 x 8 x 16" On Center | 9 | 7 | 2 | 0 |
| 2x10 16" On Center | 33 (58%) | 19 (63%) | 9 (82%) | 2 (50%) |
| 2 x 10 24" On Center | 1 | 0 | 0 | 0 |
| 2 x 12 16" On Center | 3 | 2 | 0 | 0 |
| Truss | 10 | 2 | 0 | 1 |
| **Insulation Visibility and Installation Grade** | | | | |
| Insulation Visible | 56 (98%) | 13 (43%) | 0 | 3 (75%) |
| Grade 1 Installation | 6 | 3 | 1 | 0 |
| Grade 2 Installation | 31 (61%) | 19 (73%) | 7 (64%) | 2 (67%) |
| Grade 3 Installation | 14 | 4 | 3 | 1 |
| **Type of Insulation** | | | | |
| Fiberglass Batt Insulation | 51 (89%) | 26 (87%) | 11 (100%) | 3 (75%) |
| No Insulation | 6 | 4 | 0 | 1 |

Figure 7-3 graphs the individual recorded R-values for floor insulation over unconditioned basements.

**Figure 7-3: Recorded Floor over Unconditioned Basement Insulation R-values**



## 7.4 Windows

Auditors recorded the type(s) of windows in each home, but found it difficult to verify the U-value and SHGC for most windows.[23] The 2006 and 2009 IECC prescriptive maximum fenestration U-value for windows is 0.35. There is no solar heat gain coefficient (SHGC) requirement in Connecticut.

Documented U-value and SHGC information was available for only two homes, both spec homes, where the original NFRC (National Fenestration Rating Council) sticker was visible. The U-value for one custom home was provided in the specifications. In a fourth case, auditors were able to verify argon filling from the home's specifications. In homes where the U-value could not be documented, auditors used either a lighter test or a Low-E coating detector to determine if the windows were Low-E.[24] Auditors did not test for Argon fill and did not try to guess whether or not windows had argon fill. Auditors did confirm Low-E Argon filled windows in three homes.

Table 7-9 shows that all but one of the inspected homes have double pane Low-E windows and that in three of these homes the windows are argon filled. The majority of homes (60, or 87%) have vinyl window frames; the rest (9) have wood frames. Because auditors did not test for argon, it is likely that the actual number of homes with Low-E Argon-filled windows is much higher. It is reasonable to assume the U-value of Low-E windows is 0.35 or lower and that homes with Low-E windows meet 2006 and 2009 IECC prescriptive window U-value requirements.

**Table 7-9: Inspected Homes by Type of Window**

| Predominant Window Type | All Homes (n=69) |
|---:|:---:|
| **Double Pane Low-E** | 65 (94%) |
| **Double Pane Low-E Argon** | 3 |
| **Double Pane** | 1 |

REM/Rate and IECC default values for U-value and SHGC are shown in Table 7-10. REM/Rate defaults are more detailed—addressing more window categories—than IECC defaults.[25] However, both appear to be conservative. For example, the verified U-value of the double pane, Low-E with argon, vinyl framed windows in the two 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.

[23] 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.

[24] 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.

[25] Default values are from REM/Rate version 12.95. The REM/Rate default window values are based on the 2005 ASHRAE handbook.

**Table 7-10: REM/Rate and IECC Default Values for Missing Window Data**

| Operable Window Type | REM/Rate Defaults | | 2006 & 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 | | |

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.[26] As far as 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 Connecticut are U-0.32 or lower, depending on the SHGC (See Table 7-11), we propose an overall default window U-value of 0.34. A U-0.34 window does not meet current ENERGY STAR criteria for Connecticut, and the U-value is higher than the standard U-value reported by the representatives of major window manufacturers; it may even be conservative.

[26] The Andersen representative said that the standard option for 200series windows is now Low-E with argon.

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 7-11: Version 5.0 Northern Climate ENERGY STAR Window Criteria**

| Northern Climate ENERGY STAR Window Criteria as of January 4, 2010[27] | | | |
|---|---|---|---|
| U-Value | ≤ 0.30 | = 0.31 | = 0.32 |
| SHGC | Any | ≥ 0.35 | ≥ 0.40 |

### *7.4.1 Glazing Percentage*

Table 7-12 and Figure 7-4 provide statistics on glazing percentage. Glazing percentages are window areas as a percentage of conditioned/ambient wall area. As shown, glazing percentages range from 8% to 34%; the average is 16% and the median is 15%.

**Table 7-12: Window Glazing Percentage Statistics**

| Percent Glazing Percent of Conditioned/Ambient Wall Area | All Homes (n=69) |
|---|---|
| Minimum | 8% |
| Maximum | 34% |
| Average | 16% |
| Median | 15% |

**Figure 7-4: Glazing Percentage by Home**

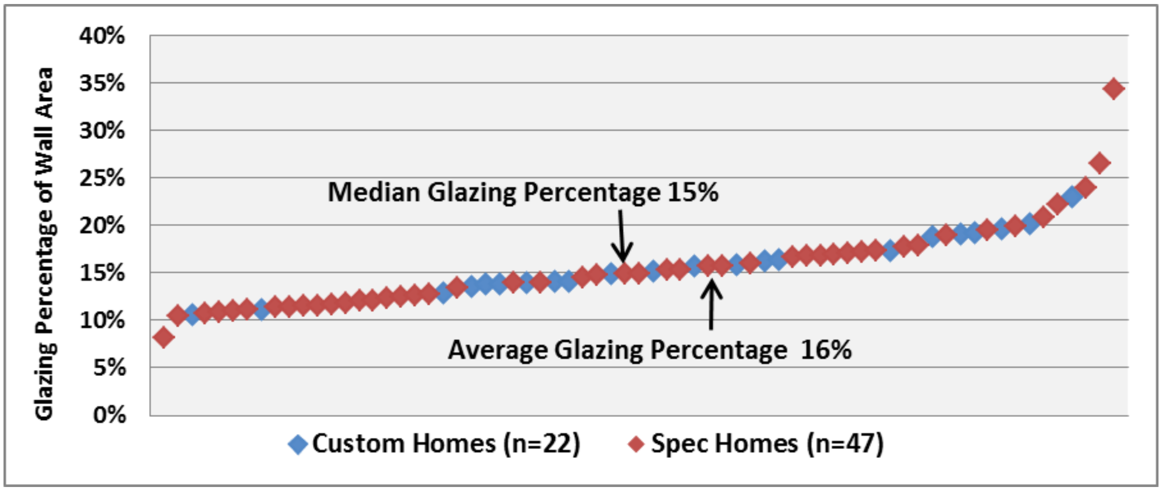



Table 7-13 shows the percent of south-oriented glazing. The percent of glazing oriented to the south ranges from zero to 77%; the average over all 69 homes is 37% and the median is 40%.

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

**Table 7-13: Percent of South Oriented Glazing**

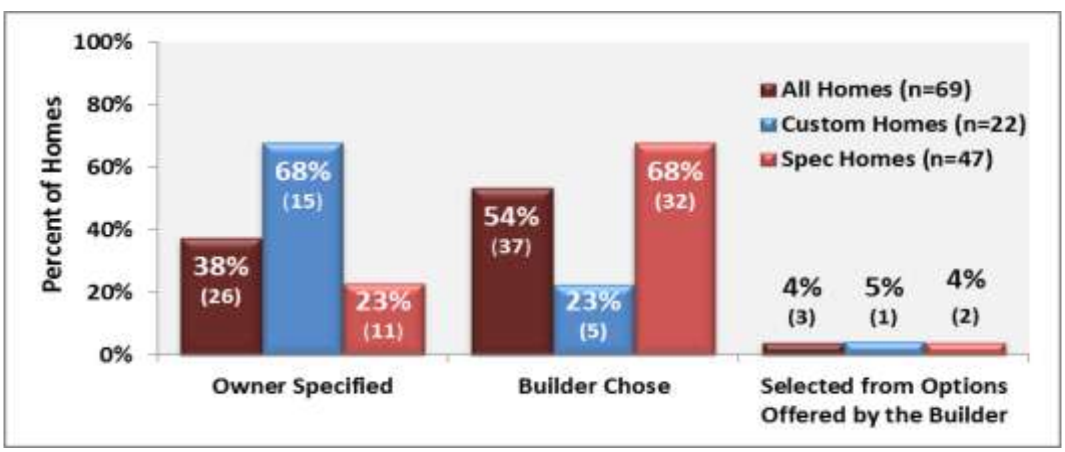
| Percent of Exterior Wall South Glazing (S, SE, SW) | All Homes (n=69) |
|---|---|
| Minimum | 0% |
| Maximum | 77% |
| **Average** | **37%** |
| Median | 40% |

## *7.4.2 Who Specified Windows*

The on-site homeowner survey asked who specified the windows. The 2006 and 2009 IECC prescriptive maximum fenestration U-value for windows is 0.35. As discussed earlier, only one inspected home has double pane windows that are not Low-E and would likely not comply with code; this is a spec home and the owner says the builder chose the windows. It is reasonable to assume that the windows in all other homes comply with code. Auditors were not able to test for Argon-fill, but it is likely that many homes have Low-E with Argon windows, which would typically have a lower (more energy efficient) U-value than a Low-E window without Argon. Without knowing the actual U-values of windows and without knowing if they are Low-E with Argon it is impossible to say whether windows specified by homeowners are more or less efficient than windows specified by builders.

Figure 7-5 shows that 38% of all homeowners say they specified the windows for their home. Owners of custom homes were more likely to say they specified the windows (68%) than owners of spec homes (23%) and less likely to say the builder specified the windows (23% of owners of custom homes versus 68% of owners of spec homes); these differences are statistically significant at the 90% confidence level.

**Figure 7-5: Who Specified Windows***




*Number of homes in parentheses.

Homeowners who said they specified the windows were asked if they remembered what they specified. Of the 26 homeowners who said they specified the windows for their home, 22 identified at least one aspect they specified:

- Eight homeowners say they specified the number of panes.
- Eleven homeowners say they specified the style of the windows.
- Twelve homeowners say they specified energy-efficient windows.
- Eight homeowners say they specified ENERGY STAR windows.

Of the 20 homeowners who say they specified energy-efficient or ENERGY STAR windows, 19 have Low-E windows and one has Low-E Argon-filled windows.

## 7.5 Doors

Auditors recorded the type(s) of the 227 doors observed in the 69 sampled homes, but were unable to verify the U-values since the original NFRC sticker was no longer present on any of the doors. The 2006 and 2009 IECC prescriptive maximum fenestration U-value for doors is 0.35.

Table 7-14 displays the distribution of the types of doors observed. The majority of the doors (71%) are steel or fiberglass. Almost one third of the doors (29%) are wood. Auditors only recorded information on doors that were part of the thermal boundary; this includes doors to unconditioned basements in homes where the floor separating conditioned space and the unconditioned basement is the thermal boundary—in some cases these are standard hollow core interior doors.

**Table 7-14: Type of Door**

| Door Type | Doors (n=227) |
|---:|:---:|
| **Steel** | 42% |
| **Fiberglass** | 29% |
| **Wood** | 29% |

Table 7-15 shows the percentage of doors with various characteristics. Most doors are insulated (74%), few have storm doors (7%), and over one-third of the doors (37%) contain glass. The average glass area in doors with glass is 6.7 square feet. Nearly all of the doors with glass (99%) have either double pane Low-E (86%) or double pane clear (13%) glass.

**Table 7-15: Door Characteristics**

| Door Characteristics | Percent of Doors (multiple responses, n=227) |
|---|---|
| Insulated | 74% |
| Storm Door | 7% |
| Glass in Door | 37% |
| Doors with Glass (n=85) | |
| Avg. Sq. Ft. of Glass/Door | 6.7 |
| Double Pane Low-E | 86% |
| Double Pane (clear) | 13% |
| Single Pane | 1% |

REM/Rate and IECC default U-values for doors are shown in Table 7-16.

**Table 7-16: REM/Rate and IECC Default U-values for Doors**

| Door Type | REM/Rate Defaults | 2006 & 2009 IECC Defaults |
|---|---|---|
| | U-Value | U-Value |
| Uninsulated Metal | n/a | 1.20 |
| Insulated Metal | n/a | 0.60 |
| Insulated, Non-Metal Edge, Max 45% Glazing, Any Glazing Double Pane | n/a | 0.35 |
| 1-3/4" Insulated Steel Door | 0.23 | 0.60 |
| 2-1/4" Solid Core Wood Door | 0.36 | 0.50 |
| 1-3/4" Solid Core Wood Door | 0.48 | 0.50 |
| 1-3/8" Solid Core Wood Door | 0.59 | 0.50 |
| 1-3/8" Hollow Core Wood Door | 0.77 | 0.50 |
| 1-3/4" Wood Panel Wood Door | 0.77 | 0.50 |
| 1-3/8" Wood Panel Wood Door | 1.11 | 0.50 |

In an effort to develop more realistic default U-values, an NMR evaluation team member talked to staff personnel at four Connecticut lumber yards that sell doors to builders of new homes; the lumber yards are in Bridgeport, Hartford, Norwich and Plainville. Representatives from all four lumber yards say almost all of the doors they sell are ENERGY STAR-qualified insulated fiberglass or steel doors; overall they sell more fiberglass than steel doors and two of the representatives say most of the exterior doors they sell have glass. The three most frequently mentioned brands are Therma-Tru®, Masonite® and Jeld-Wen®. Almost all doors by these manufacturers are ENERGY STAR qualified. (The Therma-Tru web site includes a table that shows the U-values and Solar Heat Gain Coefficients for all their doors and indicates whether or not each door is ENERGY STAR-qualified.[28])

Based on the data reported by auditors, 29% of exterior doors in inspected homes are wood. However, it may be that at least some of the doors reported as wood are actually fiberglass. The major door manufactures all offer doors that look like wood—many can be stained or painted. As an example, the following description and pictures is from the Therma-Tru web site:

> *"The Mahogany Collection™ is made with our patented AccuGrain™ technology to give the look of high-grade wood, with all of the durability of fiberglass. The exterior doors in this collection have the look and feel of a real wood front door — with solid wood square edges, architecturally correct stiles, rails and panels."*[29]

Current ENERGY STAR door criteria are shown in Table 7-17.

**Table 7-17: ENERGY STAR Door Criteria**

| ENERGY STAR Door Criteria as of January 4, 2010[30] | | |
|---|---|---|
| **Glazing Level** | **U-Value** | **SHGC** |
| **Opaque** | ≤ 0.21 | No Rating |
| **≤ ½ -Lite** | ≤ 0.27 | ≤ 0.30 |
| **> ½-Lite** | ≤ 0.32 | ≤ 0.30 |

Many doors have U-Values that are lower than required to meet ENERGY STAR criteria. The table of Therma-Tru door U-values for the three ENERGY STAR door categories shows:

- All opaque doors are U-0.14.
- One-half or less glass door U-values for ENERGY STAR-qualified doors range from 0.14 to 0.27.
- More than one-half glass door U-values for ENERGY STAR-qualified doors range from 0.22 to 0.32.

Based on the above information we propose that a conservative default door U-Value would be in the 0.30 range. A U-0.30 door is measurably lower than the 2006 and 2009 IECC prescriptive maximum of U-0.35 and measurably higher than the estimated average of U-0.24 if all doors were assumed to just meet ENERGY STAR criteria.

## 7.6 Foundation Wall Insulation

The 2006 and 2009 IECC prescriptive code requirements for foundation wall insulation are the same: minimum R-10 for continuous insulation and R-13 for cavity insulation. By code, foundation walls in homes with conditioned basement space, where the conditioned space is

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28 http://www.thermatru.com/pdfs/EstarChart.pdf
29 http://www.thermatru.com/products/entry/fiberglass-entry-doors/ccm/index.aspx
30 http://www.energystar.gov/index.cfm?c=windows_doors.pr_anat_window

bounded by a foundation wall, must 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.

As shown in Table 7-18, over four-fifths (15 or 83%) of the 18 homes with conditioned basement space bounded by a foundation wall have at least R-10 continuous or R-13 cavity insulation on these foundation walls. The average insulation level for all 18 homes with conditioned basement space bounded by foundation walls is R-17.3.

**Table 7-18: Foundation Wall Insulation Statistics**

| Foundation Wall Insulation Level | Homes with Conditioned Basement Space (n=18) |
|---|---|
| **Comparison to 2006 & 2009 IECC Prescriptive Requirement of R-10/13** | |
| **Less than R-10/13** | 3 |
| **R-10/13** | 0 |
| **More than R-10/13** | 15 (83%) |
| **R-value Statistics** | |
| **Minimum R-value** | 0.0 |
| **Maximum R-value** | 27.0 |
| **Average R-value** | **17.3** |
| **Median R-value** | 19.0 |

Of the 19 homes with conditioned basement space, 17 have foundation wall insulation. One of the two homes with conditioned basement space but no foundation wall insulation has frame floor insulation between the basement and first floor and therefore has been excluded from the foundation wall analysis. The walls are typically finished (i.e., covered in drywall) in conditioned basements; therefore, the foundation wall insulation is not usually visible. Auditors were able to visually confirm the foundation wall insulation in two homes, and recorded the insulation type, R-value, whether the insulation was cavity or continuous, and whether it was interior or exterior insulation. In most other homes auditors estimated the foundation insulation characteristics based on stud depth and insulation types observed in other areas of the home. Please note this section only represents insulation that is in contact with the 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.

Table 7-19 displays the types of foundation wall insulation auditors recorded for these 18 homes. One home has uninsulated foundation walls and no frame floor insulation between the basement and first floor. All of the homes with foundation wall insulation (17) have interior insulation. All but one of these 17 homes has fiberglass batt foundation wall insulation; one home has polystyrene insulation.

**Table 7-19: Type of Foundation Wall Insulation**

| Foundation Wall Insulation Type | Homes with Conditioned Basement Space (n=18) |
|---|---|
| Insulation Visible | 2 |
| Fiberglass Batts | 16 (89%) |
| Polystyrene | 1 |
| Uninsulated | 1 |

## 7.7 Rim and Band Joist Insulation

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. This portion of the code is new, as of 2009 IECC; rim/band joists are not addressed under the 2006 IECC.[31] 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 information.

[31] The rim/band joist mandatory requirement may be met via visual inspection or, as an alternative, by achieving an air leakage level of 7 or less ACH50.

[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 7-20 displays a summary of the rim and band joist insulation recorded during the on-site visits. The average R-value ranges from R-0.0 to R-16.4, depending on the location of the joists. The majority of rim and band joist insulation is located between conditioned spaces and ambient (outside) conditions. These joists have an average R-value of R-16.4, the majority are spaced 16 inches apart (98%), and 39 out of 55 homes (71%) with observable insulation have a Grade II installation.

**Table 7-20: Summary of Rim/Band Joist Insulation**

| Rim/Band Joist Location → | Cond/ Ambient (n=62)* | Cond/ Garage (n=8)* | Uncond Basement/ Ambient (n=18)* | Uncond Basement /Garage (n=2)** | Uncond Basement/ Sunspace (n=1)** |
|---|---|---|---|---|---|
| **Average R-value** | R-16.4 | R-14.3 | R-6.9 | R-0.0 | R-0.0 |
| **Framing** | | | | | |
| **Joist 16" On Center** | 61 (98%) | 8 | 18 | 2 | 1 |
| **Joist 24" On Center** | 1 | 0 | 0 | 0 | 0 |
| **Insulation Installation Grade** | | | | | |
| **Grade I Installation** | 3 | 0 | 1 | n/a | n/a |
| **Grade II Installation** | 39 (71%) | 5 (83%) | 5 (63%) | n/a | n/a |
| **Grade III Installation** | 13 | 1 | 2 | n/a | n/a |
| **Type of Insulation** | | | | | |
| **% Fiberglass Batt** | 50 (80%) | 6 (75%) | 6 (33%) | n/a | n/a |
| **No Insulation** | 8 (12%) | 2 | 10 (56%) | 2 | 1 |

*There were a number of homes that had uninsulated rim/band joists. Installation grade percentages are based on homes that had insulated rim/band joists.
**For these locations the rim/band joists were uninsulated.

As previously mentioned, conditioned/ambient rim and band joist insulation is the most prevalent, and as such is the most important in terms of overall building efficiency. Among all homes, conditioned/ambient rim and band joists have R-values ranging from R-0 (uninsulated) to R-36, with an average of R-16.4 (Table 7-21).

**Table 7-21: Conditioned/Ambient Rim/Band Joist Insulation**

| Conditioned/Ambient Rim/Band Joist R-values | All Homes (n=62) |
|---|---|
| **Minimum R-value** | 0 |
| **Maximum R-value** | 36 |
| **Average R-value** | **16.4** |
| **Median R-value** | 19 |

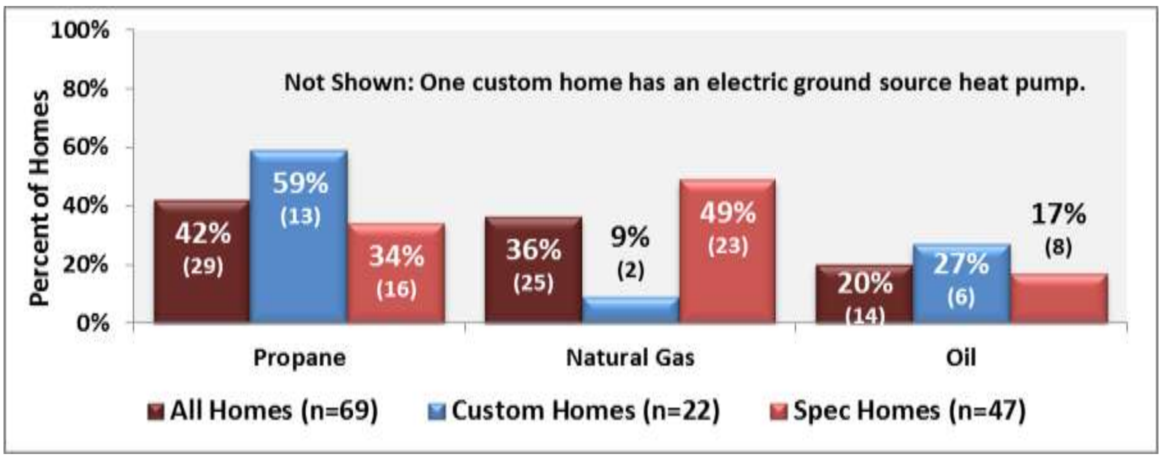
# 8 Heating and Cooling

There are no prescriptive requirements for heating or cooling system efficiencies under either 2006 or 2009 IECC other than they need to meet federal minimum efficiency standards. All heating and cooling systems in inspected homes meet federal minimum efficiency standards.

## 8.1 Heating Systems

Most inspected homes have propane (42%) or natural gas (36%) heating systems and most homes have furnaces (70%). Most heating systems are installed in unconditioned basements (74%). Figure 8-1 and Figure 8-2 show, respectively, the primary heating fuels and types of heating systems. Figure 8-1 shows custom homes are more likely than spec homes to have a propane heating system and less likely to have a natural gas heating system; these differences are statistically significant at the 90% confidence level. Custom homes are also more likely than spec homes to have an oil heating system, but the difference is not statistically significant at the 90% confidence level. Not shown in Figure 8-1 is one custom home with an electric ground source heat pump (GSHP) heating system.

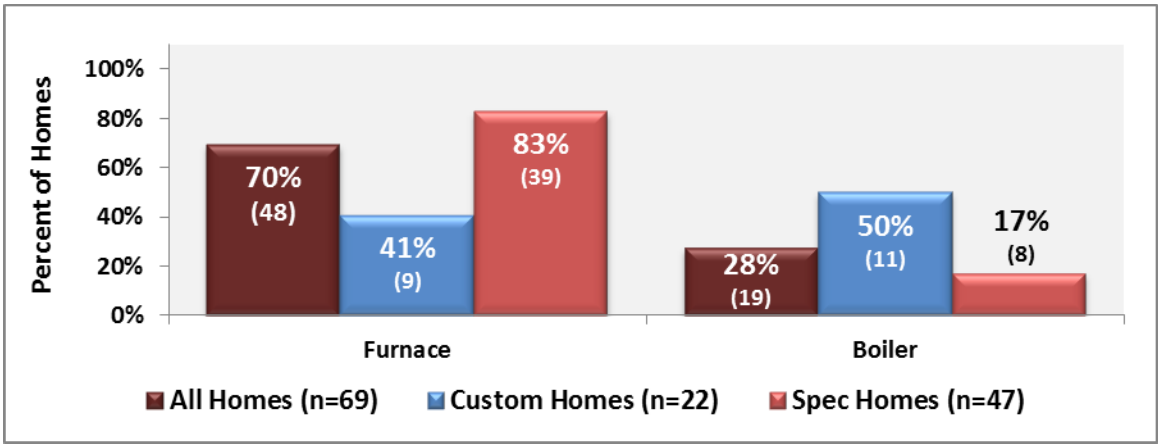
**Figure 8-1: Primary Heating Fuel***




*Number of homes in parentheses.

Figure 8-2 shows the majority of homes (70%) have furnaces. Custom homes are less likely than spec homes to have a furnace and more likely to have a boiler; these differences are statistically significant at the 90% confidence level. Heating systems in two homes are not shown in Figure 8-2. One custom home has a GSHP, an open loop water-to-air system with a Coefficient of Performance (COP) of 5.1 and an Energy Efficiency Ratio (EER) of 16, which met the criteria for ENERGY STAR qualification when it was installed in 2010.[33] Another custom home has a Quietside ENERGY STAR-qualified propane dual purpose water heater.

**Figure 8-2: Heating System Type***




* Number of homes in parentheses. Not shown: one custom home has an electric ground source heat pump and another custom home has a propane dual purpose water heater.

A total of 73 heating systems were observed in the 69 inspected homes; four homes have two heating systems. The majority of heating systems in both custom and spec homes are located in unconditioned basements; 74% of all heating systems, 70% of heating systems in custom homes and 76% of heating systems in spec homes.

33 This system does not meet Tier 2 Requirements for ENERGY STAR qualification, which became effective January 1, 2011.

There are several ways to group heating systems to compare efficiencies. Table 8-1 shows Annual Fuel Utilization Efficiency (AFUE) statistics for all fuel-fired heating systems, gas furnaces (natural gas and propane), gas boilers, oil furnaces and oil boilers. For all but oil furnaces, the average and median AFUEs meet ENERGY STAR-qualification criteria. [34]

**Table 8-1: Furnace and Boiler Efficiencies**

| Heating System Efficiency Statistics | All Fuel Fired Heating Systems (n=70) | Gas Furnaces (n=49) | Gas Boilers (n=7) | Oil Furnaces (n=3) | Oil Boilers (n=11) |
|---|---|---|---|---|---|
| **Minimum AFUE** | 80.0 | 80.0 | 82.0 | 80.5 | 83.6 |
| **Maximum AFUE** | 98.0 | 98.0 | 97.3 | 83.4 | 87.5 |
| **Average AFUE** | **90.7** | **92.5** | **90.3** | **81.6** | **85.3** |
| **Median AFUE** | 92.1 | 92.1 | 90.0 | 81.0 | 85.3 |

Table 8-2 compares the efficiencies of heating systems in custom and spec homes. As shown, for all but oil furnaces, the average AFUE of heating systems is higher in custom homes than in spec homes. Differences in the AFUEs of gas furnaces and oil boilers are statistically significant at the 90% confidence level.

**Table 8-2: Furnace and Boiler Efficiencies in Custom and Spec Homes**

| Average Heating System Efficiency (AFUE) | All Homes | Custom Homes | Spec Homes |
|---|---|---|---|
| ***All Fuel Fired Heating Systems (n=70; 20 custom, 50 spec)*** | *90.7* | *91.0* | *90.6* |
| **Gas Furnaces (n=49: 9 custom, 40 spec)** | **92.5** | **94.8 *** | **92.0*** |
| **Gas Boilers (n=7: 5 custom, 2 spec)** | 90.3 | 91.1 | 88.5 |
| **Oil Furnaces (n=3: 1 custom, 2 spec)** | 81.6 | 80.5 | 82.2 |
| **Oil Boilers (n= 11: 5 custom, 6 spec)** | **85.3** | **86.2*** | **84.6*** |

*Significantly different at the 90% confidence level.

User Defined Reference Home (UDRH) inputs used in the process of estimating program savings, may group heating systems by fuel and type of distribution system. Table 8-3 shows that, overall, fuel-fired air distribution heating systems have a higher average AFUE than

[34] ENERGY STAR criteria for furnaces and boilers when the homes inspected in this study were built were:

- Gas Furnaces—90 AFUE or greater
- Oil Furnaces—85 AFUE or greater
- Boilers—85 AFUE or greater

hydronic distribution systems. Propane air distribution heating systems have the highest average AFUE (92.8) and oil air distribution heating systems the lowest average AFUE (83.3).

**Table 8-3: Heating System Efficiencies by Fuel and Distribution System**

| Heating System Efficiency Statistics | All Fuel-Fired Air Distribution (n=55) | Natural Gas Air Distribution (n=26) | Propane Air Distribution (n=24) | Oil Air Distribution (n=5) | All Fuel-Fired Hydronic Distribution (n=15) | Propane Hydronic Distribution (n=6 ) | Oil Hydronic Distribution (n=9 ) |
|---|---|---|---|---|---|---|---|
| Min AFUE | 80.0 | 80.0 | 80.0 | 80.5 | 82.0 | 80.0 | 83.6 |
| Max AFUE | 98.0 | 95.5 | 98.0 | 86.2 | 97.3 | 95.5 | 87.5 |
| **Average AFUE** | **91.7** | **92.4** | **92.8** | **83.3** | **87.0** | **92.4** | **85.2** |
| Median AFUE | 92.1 | 92.4 | 92.1 | 83.4 | 86.0 | 92.4 | 85.3 |

Figure 8-3 graphs the heating system efficiencies for the 70 fuel-fired heating systems with known AFUEs observed in inspected homes. The five least efficient heating systems observed are a mix of natural gas, propane and oil furnaces; the five most efficient are a mix of propane and natural gas furnaces and propane hot water boilers.

**Figure 8-3: Heating System Efficiencies by Type of System**

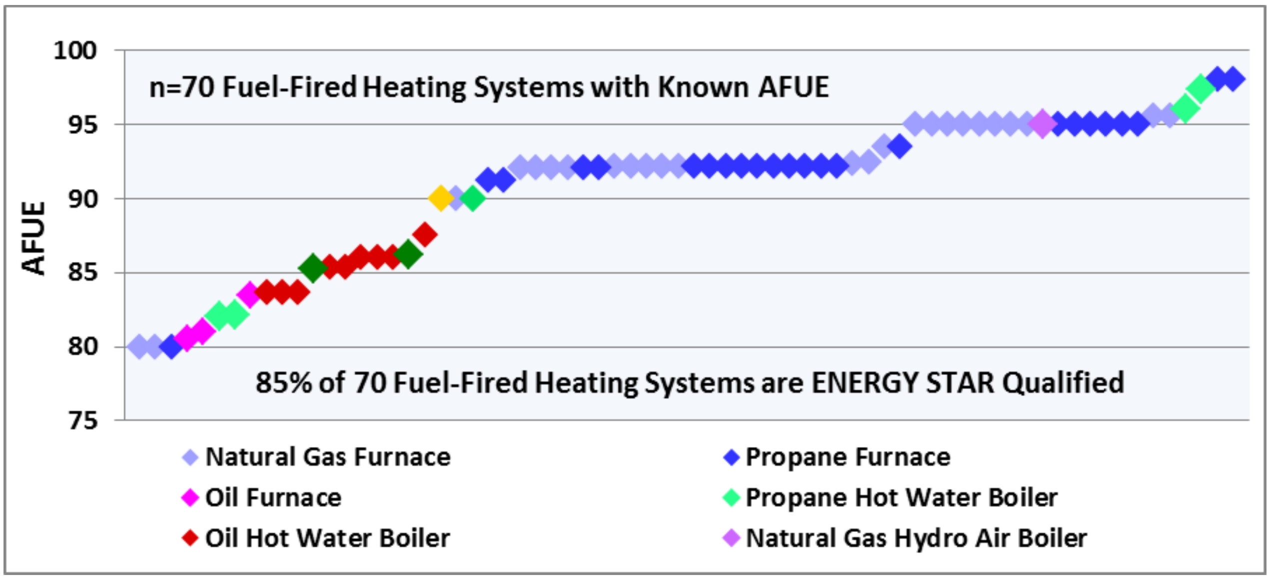
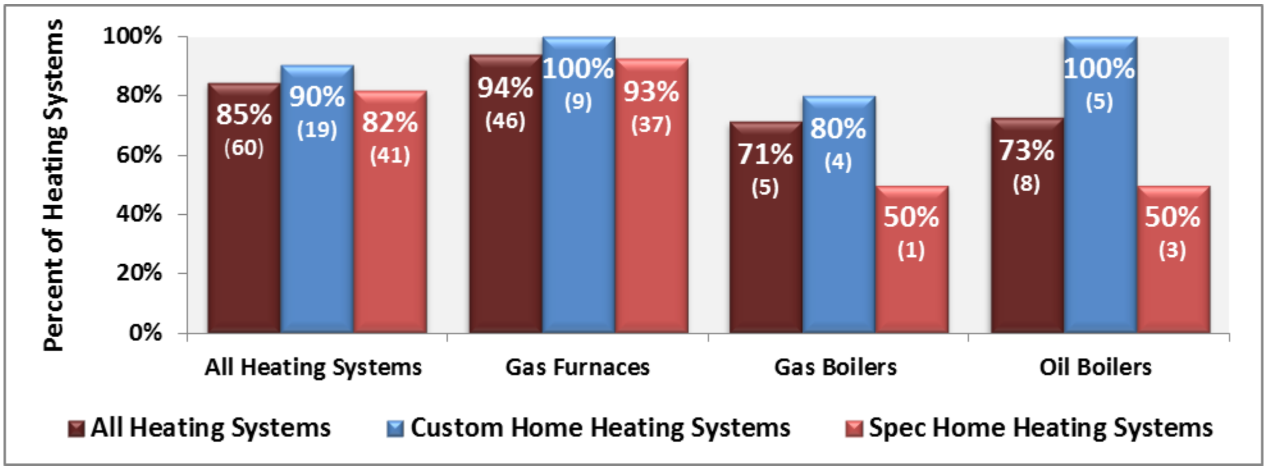


Figure 8-4 shows the percentages of ENERGY STAR fuel-fired heating systems in all, custom and spec homes. Overall, 85% of fuel-fired heating systems are ENERGY STAR. All gas furnaces and oil boilers in custom homes are ENERGY STAR-qualified, compared to 93% of gas furnaces and 50% of oil boilers in spec homes; these differences are statistically significant at the 90% confidence level.

**Figure 8-4: Percent ENERGY STAR Heating Systems***




* Number of heating systems in parentheses.

### *8.1.1 Supplemental Heat Sources*

Most inspected homes (80% or 55 of 69 homes) have a fireplace and/or stove; 86% of 22 custom homes and 77% of 47 spec homes. Of the 55 homes with a fireplace and/or stove, 27% (15 homes) have 2 or more fireplaces and stoves. Table 8-4 shows the percentages of homes with propane, wood, natural gas, and electric fireplaces and stoves. As shown, in most homes fireplaces and stoves are fueled by propane (44%). However, custom homes are significantly more likely to have propane fireplaces and stoves (63%) than spec homes (33%). The most frequently observed fireplace and stove fuel in spec homes is natural gas (42%); none of the inspected custom homes have natural gas fireplaces or stoves and this difference is statistically significant. Fifteen homes have wood burning fireplaces (7 custom and 6 spec homes); fireplace doors are gasketed in only six of these homes (4 custom and 2 spec homes).

**Table 8-4: Fireplace and Stove Fuel**

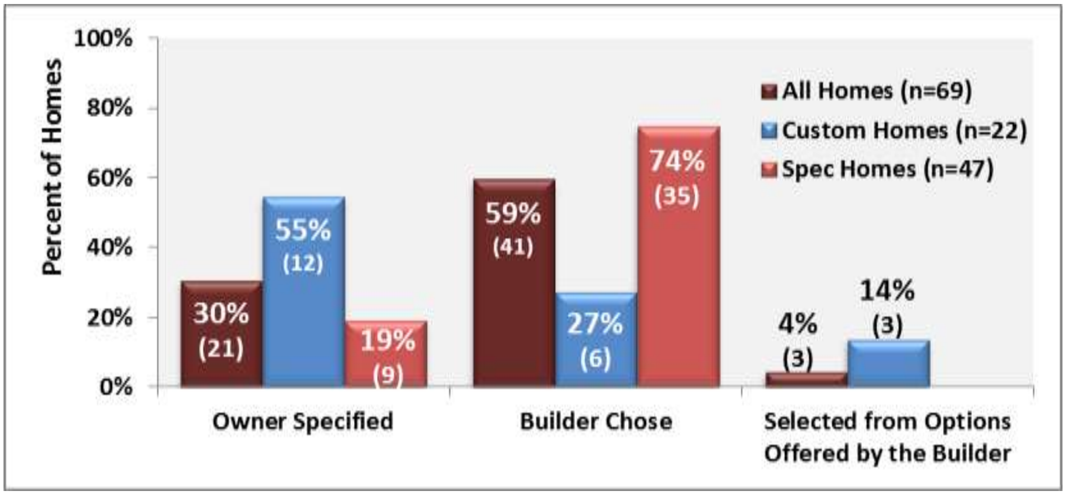
| Fireplace or Stove Fuel | All Homes (n=55) | Custom Homes (n=19) | Spec Homes (n=36) |
|---|---|---|---|
| Propane | 24 (44%) | **12 (63%)*** | **12 (33%)*** |
| Wood | 15 (27%) | 7 (37%) | 8 (22%) |
| Natural Gas | 15 (27%) | **0 (0%)*** | **15 (42%)*** |
| Electric | 1 | 0 | 1 |

*Significantly different at the 90% confidence level.

### 8.1.2 Who Specified Heating Systems

The on-site homeowner survey asked who specified the heating system. Figure 8-5 shows that 30% of all homeowners say they specified the heating system for their home. Owners of custom homes were more likely to say they specified the heating system (55%) than owners of spec homes (19%), less likely to say the builder specified the heating system (27% of owners of custom homes versus 74% of owners of spec homes), and more likely to say they selected from options offered by the builder (14% of owners of custom homes versus 4% of owners of spec homes); all these differences are statistically significant at the 90% confidence level.

**Figure 8-5: Who Specified Heating System***




*Number of homes in parentheses.

Homeowners were asked what aspects of the heating system they specified. Of the 21 homeowners who say they specified the heating system for their home, 15 identified one or more aspects:

- Six home owners say they specified the heating system fuel.
- Eight homeowners say they specified the type of heating system.
- Ten homeowners say they specified an energy-efficient and/or ENERGY STAR-labeled heating system.

Only four homeowners (one owner of a custom home and three owners of spec homes) specified ENERGY STAR-labeled heating systems and all four have ENERGY STAR-heating systems.

Table 8-5 shows the average AFUE of heating systems in homes where the owner said they specified the heating system (91.4 AFUE) is slightly higher than in homes where the builder specified the heating system (90.2 AFUE), but the difference is not statistically significant at the 90% confidence level.

**Table 8-5: Efficiency Statistics by Who Specified Heating System**

| Heating System Efficiency Statistics | Builder Specified Heating Systems (n=41) | Owner Specified Heating Systems (n=18)* | Owner Specified Energy-Efficient Heating System (n=9)** |
|---|---|---|---|
| **Minimum AFUE** | 80.0 | 82.0 | 82.1 |
| **Maximum AFUE** | 95.0 | 98.0 | 97.3 |
| **Average AFUE** | **90.2** | **91.4** | **90.8** |
| **Median AFUE** | 92.1 | 95.0 | 95.0 |

*No efficiency information was available for two of the heating systems in homes where the owner specified the heating system. Both homes are custom homes with hydro-air boilers. In one case auditors did not record the model number and in the other home there was no nameplate on the boiler. A third home is not included because the heating system does not have an AFUE rating; it is an ENERGY STAR-qualified GSHP with a COP of 5.1.

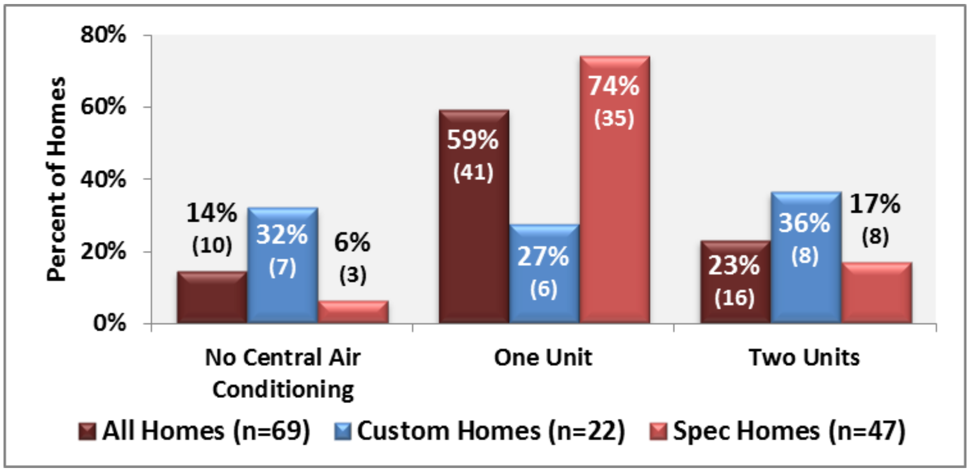
**No efficiency information was available for one of heating systems in a home where the owner said he specified an ENERGY STAR-labeled system. This is the custom home with a hydro-air boiler where auditors did not record the model number.

## 8.2 Cooling

There are no prescriptive requirements for heating or cooling system efficiencies under either 2006 or 2009 IECC other than they need to meet federal minimum efficiency standards. All cooling systems in inspected homes meet federal minimum efficiency standards.

Most inspected homes (59 of 69 homes or 86%) have central air conditioning. Figure 8-6 shows the number of central air conditioning units per home. As shown, 14% of inspected homes (10 homes) do not have central air conditioning, 59% (41 homes) have one central air conditioning unit, and 23% (16 homes) have two units. Two homes, one custom and one spec, with three central air conditioning units each are not shown in Figure 8-6. Custom homes are more likely than spec homes to not have central air conditioning (32% versus 6%) and less likely to have only one air conditioning unit (27% versus 74%); these differences are statistically significant at the 90% confidence level.

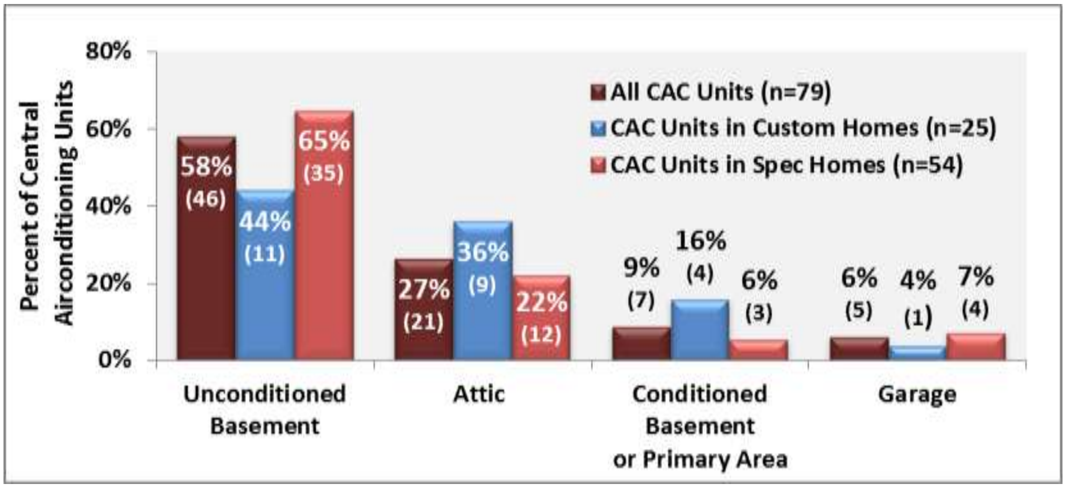
**Figure 8-6: Number of Central Air Conditioning Units per Home***




*Number of homes in parentheses.

Auditors reported on a total of 79 cooling systems in the 59 homes with central air conditioning. Figure 8-7 shows most cooling systems (46 out of 79 units or 58%) are located in unconditioned basements, 27% are located in attics, 9% in conditioned basements or other conditioned space, and 6% in garages. Custom homes are less likely to have cooling systems located in unconditioned basements and more likely to have them installed in attics or conditioned space than spec homes. The only statistically significant difference at the 90% confidence level between custom and spec homes is that air conditioning units in custom homes are less likely than units in spec homes to be located in an unconditioned basement (44% versus 65%).

**Figure 8-7: Cooling System Location***




*Number of central air conditioning units in parentheses.

Auditors recorded model numbers for all but two of the central air conditioning units observed in inspected homes. All Seasonal Energy Efficiency Ratio (SEER) and 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. The cooling system in one home does not have a SEER rating; this home has a WaterFurnace Envision geothermal heat pump with a COP of 5.1 and an EER of 16, which met the criteria for ENERGY STAR qualification when it was installed in 2010.[35]

[35] This system does not meet Tier 2 Requirements for ENERGY STAR qualification, which became effective January 1, 2011.

Most (74%) of the 76 central air conditioning units with SEER information available are SEER 13 units. Table 8-6 shows that, overall, the SEER of central air conditioning range from 13.0 to 16.0. The median SEER is the same for custom and spec homes, but the average SEER of 13.8 in custom homes compared to 13.2 in spec homes is significantly different at the 90% confidence level.

**Table 8-6: Central Air Conditioning (CAC) Efficiency**

| Central Air Conditioning Efficiency Statistics | All CAC Units (n=76) | CAC Units in Custom Homes (n=22) | CAC Units in Spec Homes (n=54) |
|---|---|---|---|
| **Minimum SEER** | 13.0 | 13.0 | 13.0 |
| **Maximum SEER** | 16.0 | 16.0 | 15.0 |
| **Average SEER** | **13.4** | **13.8*** | **13.2*** |
| **Median SEER** | 13.0 | 13.0 | 13.0 |

*Significantly different at the 90% confidence level.

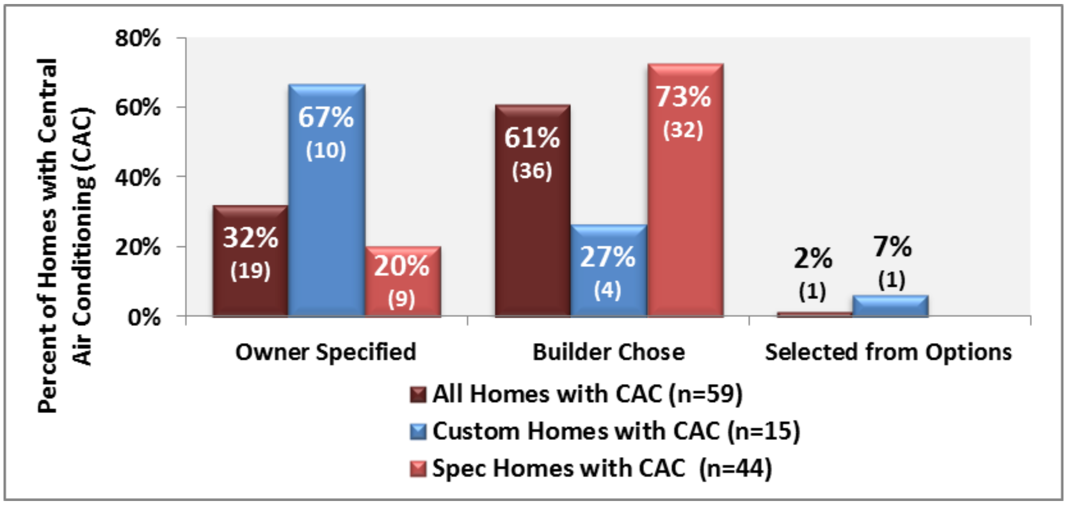
In addition to the WaterFurnace Envision system, there are 14 split system central air conditioners in 12 homes that may be ENERGY STAR-qualified. When looking up the model number of the outdoor unit of a split system in the AHRI directory there were often hundreds or, in some cases, thousands of SEER and EER combinations, some that met ENERGY STAR criteria and some that did not depending on the indoor unit.[36]

[36] To be ENERGY STAR-qualified a split-system central air conditioner needs to have an SEER of at least 14.5 and an EER of at least 12.0.

### *8.2.1 Who Specified Cooling Systems*

The on-site homeowner survey asked who specified the cooling system. Figure 8-8 shows that 32% of all homeowners with central air conditioning say they specified the central air conditioning system for their home. Owners of custom homes were more than three times as likely to say they specified the central air conditioning system (67%) than owners of spec homes (20%); this difference is statistically significant at the 90% confidence level. Owners of spec homes were more than twice as likely to say the builder specified the central air conditioning system (73%) than owners of custom homes (27%); this difference is statistically significant at the 90% confidence level.

**Figure 8-8: Who Specified Cooling System***




*Number of homes in parentheses.

Homeowners were asked if they remembered what they specified. Of the 19 homeowners who say they specified the central air conditioning system for their home, 12 identified one or more aspects:

- Four homeowners say they specified whether or not to install central air conditioning.
- Four homeowners say they specified the type of air conditioning system.
- Seven homeowners say they specified an energy-efficient air conditioning system.

Only two of the seven homeowners who say they specified an energy-efficient system say they specified an ENERGY STAR-labeled system; one is the owner and builder of a custom home with an SEER 16 ENERGY STAR-qualified system and the other is the owner of a spec home with an SEER 13.5 system (not ENERGY STAR-qualified).

Only three inspected homes have SEER 16 central air conditioners; two are custom homes where the owner is also the builder and both owners say they specified an energy-efficient cooling system, but only one says he specified an ENERGY STAR-labeled system. The third home with an SEER 16 air conditioner is a custom home where the owner says the builder chose the central air conditioner. Of 11 homes with ENERGY STAR-qualified central air conditioners, homeowners indicate that they specified the central air conditioner in 5 of these homes and builders chose the air conditioner in 6 of the homes.

Table 8-7 shows the average SEER of cooling systems in homes where owners say they specified the cooling system is higher than in homes where the builder specified the cooling system, and the average SEER of cooling systems in homes where the homeowners say they specified an energy-efficient air conditioner is higher than in homes where the homeowners indicated they specified the air conditioner, but did not specify an energy-efficient air conditioner. These differences in average SEER are not statistically significant at the 90% confidence level.

**Table 8-7: Efficiency Statistics by Who Specified Cooling System**

| Cooling System Efficiency Statistics | Builder Specified Cooling System (n=41) | Owner Specified Cooling Systems (n=18)* | Owner Specified Energy-Efficient Cooling System (n=7) |
|---|---|---|---|
| Minimum SEER | 13.00 | 13.00 | 13.00 |
| Maximum SEER | 16.00 | 16.00 | 16.00 |
| **Average SEER** | **13.33** | **13.69** | **13.86** |
| Median SEER | 13.00 | 13.00 | 13.00 |

*Auditors were unable to verify the efficiency of the air conditioner in one of the homes where the homeowner said he specified the cooling system.

## 8.3 HVAC Performance Testing

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.[37] This section of the report provides an overview of the results from this data collection effort. More detail on in-field measurements, equipment, protocols, and analytical procedures can be found in Appendix F HVAC Performance Testing.

The measurements required to properly assess the operating performance of the CACs included air side temperatures and flow rates along with electric power draws of the condensing units and blower motors with controls. Although duct 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.

[37] 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.

The overall results of these measurements are summarized in Table 8-8, which shows the average values of the 41 CAC systems for which performance data were collected:

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

| CAC Testing Results (n=41) | Rated | Operating | Difference | Relative Error |
|---|---|---|---|---|
| **Capacity Btuh** | 37,024 | 31,329 | -15.4% | 8.4% |
| **SEER** | 13.2 | 12.0 | -8.9% | 6.5% |

The average rated capacity and efficiency is 37,024 Btuh (3.09 tons) and 13.2 SEER, as shown. The average operating capacity and efficiency are somewhat lower, at 31,329 Btuh (2.61 tons) and 12.0 SEER.

Statistical Z tests confirm that the average values in Table 8-8 are statistically significant, indicating that these values are valid indicators of the field performance condition overall. However, the individual site performance comparisons may not be valid due to inherent measurement errors.

The capacity difference is primarily due to reduced airflow, but low refrigerant charge, excessively long refrigerant lines, dirty evaporator and condenser coils, and several other design and operating deficiencies may also contribute to this. The rated airflow is 400 CFM per ton, whereas the average measured air flow is significantly lower at 309 CFM per ton. This deficiency tends to reduce the cooling capacity more than the efficiency.

Reduced airflow is quite common in residential CAC systems throughout the country, where averages range from 300 to about 370 CFM per ton. Studies have found that undersized ductwork with long runs or too many turns is common, and dirty evaporator coils and/or filters also contribute to low airflow problems.

Equipment efficiency, similar to equipment capacity, is primarily reduced by poor heat transfer through dirty evaporator and/or condenser coils, improper refrigerant (especially low) charge and low air flow. It may also be affected by undersized or excessively long refrigerant lines.

The differences between the rated and operating performance are multifaceted, involving numerous possible installation and/or operational deficiencies, and the field deficiencies leading to loss of capacity and efficiency behave interactively. It is difficult to determine what specific deficiencies are causing a difference. To determine if the refrigerant charge is correct, for example, requires attaching pressure gauges and thermometers to the refrigerant lines, which was beyond the scope of this study. Rated conditions are ideal, assuming the equipment will be installed and operated as intended. That said, field conditions are hardly ever ideal and they usually result in reduced performance.

## 8.4 *Heating and Cooling Equipment Sizing—Manual J*

One of the objectives of this 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 to size the cooling and heating systems was considered to be acceptable as long as REM design loads (cooling and heating loads under design conditions) agreed closely with MJ8 design loads.

Therefore, the evaluation team chose three homes at random in different weather regions to analyze using both MJ8 and REM to compare results. Table 8-9 captures the results of the two methods:

**Table 8-9: Comparison of MJ8 Cooling and Heating Loads with REM/Rate**

| Site Number | Manual J8 Loads | | REM/Rate Loads | | Percent Difference | |
|---|---|---|---|---|---|---|
| | Heating | Cooling | Heating | Cooling | Heating | Cooling |
| 1 | 68,073 | 31,320 | 76,300 | 30,300 | -10.8% | 3.4% |
| 2 | 63,909 | 33,258 | 69,600 | 34,400 | -8.2% | -3.3% |
| 3 | 60,412 | 24,443 | 56,900 | 27,200 | 6.2% | -10.1% |
| **Average** | **64,131** | **29,673** | **67,600** | **30,633** | **-5.1%** | **-3.1%** |

The last two columns show the differences in heating and cooling loads calculated by the two methods. It was found that the greatest discrepancy was -10.8% in the heating load for the first site. The average loads and differences of all three sites indicate that REM design load calculations are sufficiently close to those of MJ8 to justify the application of REM to all the homes in this sample. The more important cooling load estimates indicate closer agreement individually and overall at a -3.1% difference.

The REM/Rate input files were run to calculate the design cooling and/or heating loads for the 69 inspected homes, and the results are indicative of the MJ8 equipment sizing requirements. Ten of the 69 homes do not have central cooling systems and one home does not have heating system data. 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.

### 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 8-10 shows the results for the 59 homes with central cooling. Following the conditioned floor area, the next two columns in Table 8-10 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.[38] The cooling system size ratio is the ratio of the actual cooling tons to the proper equipment size tons (REM/Rate design load rounded up to the nearest half ton capacity). As shown, the average size ratio is 1.99, indicating that the average installed cooling system rated capacity is nearly twice the properly sized system capacity. The maximum ratio of all 59 sites is 3.25, and the minimum is 1.00. There were two sites at exactly 1.00, while the other 57 sites all have oversized cooling systems based on MJ8 sizing allowances. Therefore, 57 out of 59 sites, or 97%, have oversized cooling systems, with size ratios ranging from 1.20 to 3.25.

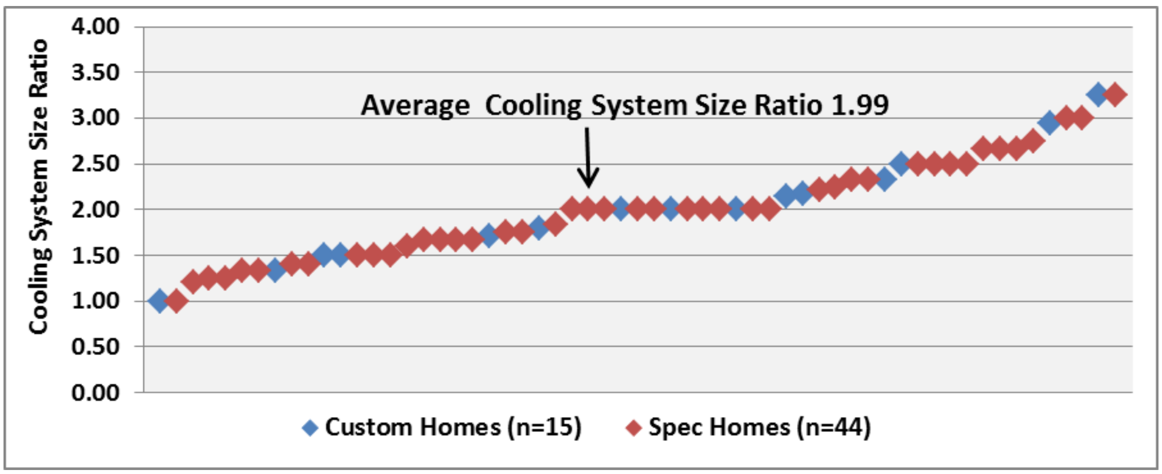
[38] The “Proper Equipment Size Cooling Tons” is the REM/Rate load in tons rounded up to the nearest half ton. This was done for each site, so the average of those (2.1) is not a rounded number and is not equal to the average REM/Rate load in tons times the MJ8 sizing factor.

**Table 8-10: Comparison of Actual Cooling Capacities and REM/Rate Design Loads**

| All Homes with Central Air Conditioning (n=59) | Conditioned Floor Area (CFA) Sq. Ft. | Actual Cooling Capacity BTU/hr | Actual Cooling Tons | REM/Rate Cooling Load BTU/hr | REM/Rate Cooling Load Tons | Proper Equipment Size Cooling Tons | Cooling System Size Ratio |
|---|---|---|---|---|---|---|---|
| **Minimum** | 1,300 | 24,000 | 2.0 | 10,000 | 0.8 | 1.0 | 1.00 |
| **Maximum** | 7,090 | 126,000 | 10.5 | 53,400 | 4.5 | 4.5 | 3.25 |
| **Average** | **2,921** | **48,953** | **4.1** | **22,480** | **1.9** | **2.1** | **1.99** |
| **Median** | 2,596 | 48,000 | 4.0 | 20,300 | 1.7 | 2.0 | 2.00 |

Figure 8-9 graphs the cooling system size ratios by home. As shown, both custom and spec homes have a wide range of cooling system size ratios and show a similar distribution across the sample.

**Figure 8-9: 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 in a hurry.

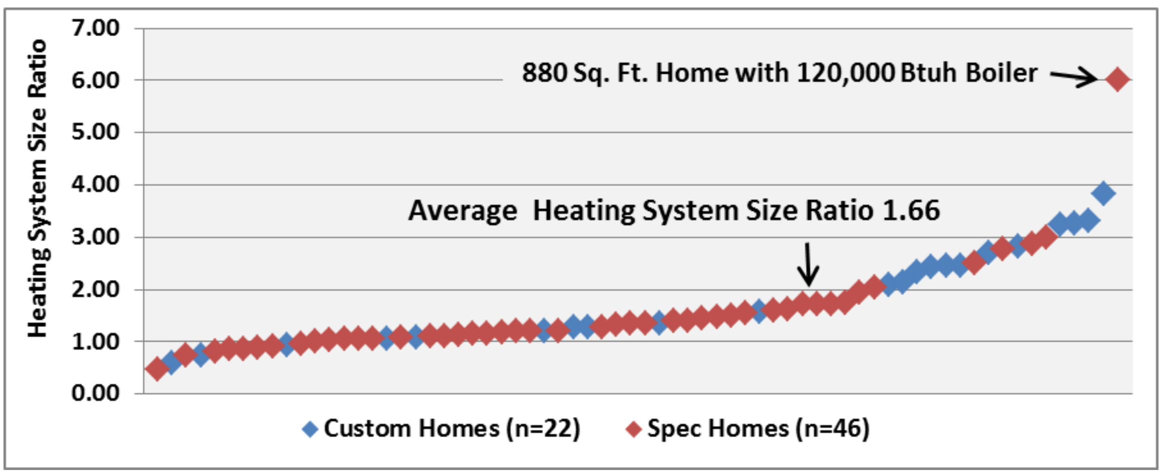
Table 8-11 shows the results for the 68 homes with heating capacity data. Following the conditioned floor area, the next column in Table 8-11 shows the installed heating capacities in BTUs per hour (Btuh). Next, the REM/Rate design loads are shown in Btuh, followed by the heating system size ratio. The heating system size ratio was calculated by taking the ratio of the installed heating capacity to the adjusted (rounded up to the next 10,000 Btuh to match the next modular equipment capacity available) REM/Rate heating load. The average heating equipment size ratio is 1.66, which is surprisingly low, but even more surprising is the fact that 11 of the 68 sites (16%) have undersized heating system equipment, with a minimum size ratio of 0.46. Perhaps these results are an indication that fireplaces and stoves are being utilized significantly in many of these homes. The remaining 57 homes (84%) have oversized heating systems, with size ratios ranging from 1.01 to 6.00. The average size ratio is higher for custom homes (2.01) than spec homes (1.49) and this difference is significantly significant at the 90% confidence level.

**Table 8-11: Comparison of Actual Heating Capacities and REM/Rate Design Loads**

| All Homes with Heating System Data (n=68) | Conditioned Floor Area Sq. Ft. | Actual Heating Capacity BTU/hr | REM/Rate Heating Load BTU/hr | Heating System Size Ratio |
|---|---|---|---|---|
| **Minimum** | 880 | 32,000 | 14,600 | 0.46 |
| **Maximum** | 7,090 | 256,000 | 143,400 | 6.00 |
| **Average** | **2,770** | **102,425** | **64,674** | **1.66** |
| **Median** | 2,487 | 95,000 | 66,100 | 1.35 |

Figure 8-10 graphs the heating system size ratios by home. As shown, custom homes tend to have higher heating system size ratios than spec homes; the difference between the average heating system size ratios for custom and spec homes is not significantly different at the 90% confidence level.

**Figure 8-10: Heating System Size Ratios by Home**

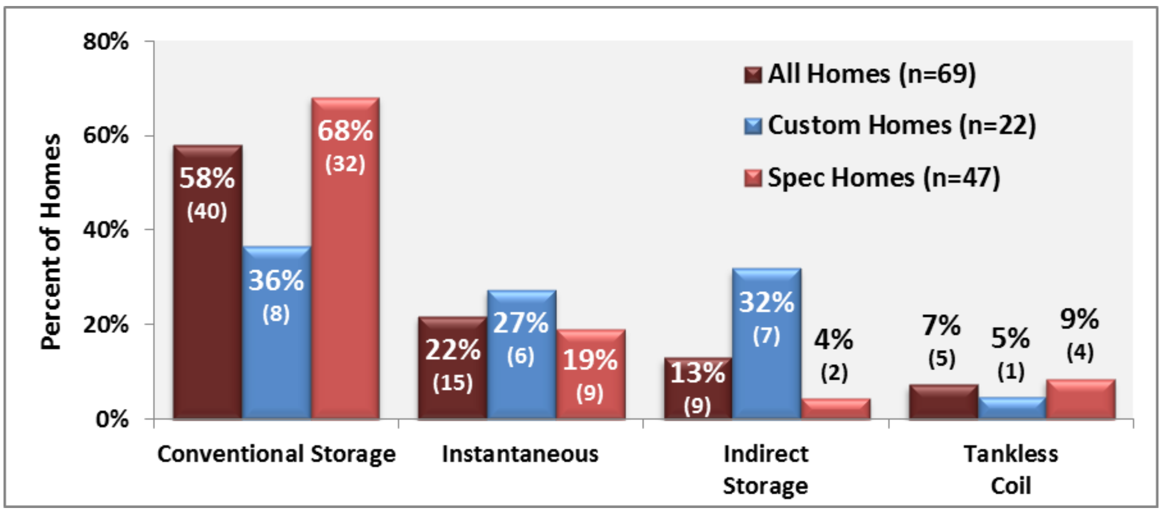


## 8.5 Water Heating

There are no prescriptive requirements for water heating efficiencies under either 2006 or 2009 IECC other than they need to meet federal minimum efficiency standards. All water heaters in inspected homes meet federal minimum efficiency standards.

More than one-half of inspected homes have conventional storage tank water heaters. Figure 8-11 shows that 58% of homes have conventional storage tank water heaters, 22% have instantaneous water heaters, 13% have indirect storage tank systems that use the home's boiler heating system to heat water, and 7% have boiler heating systems with tankless coil water heating. Custom homes are less likely than spec homes to have a conventional storage tank water heater (36% of custom homes versus 68% of spec homes) and more likely to have an indirect storage water heating system (32% of custom homes versus 4% of spec homes) and these differences are statistically significant at the 90% confidence level. Custom homes are also more likely than spec homes to have an instantaneous water heating system and less likely to have a tankless coil system, but these differences are not statistically significant.

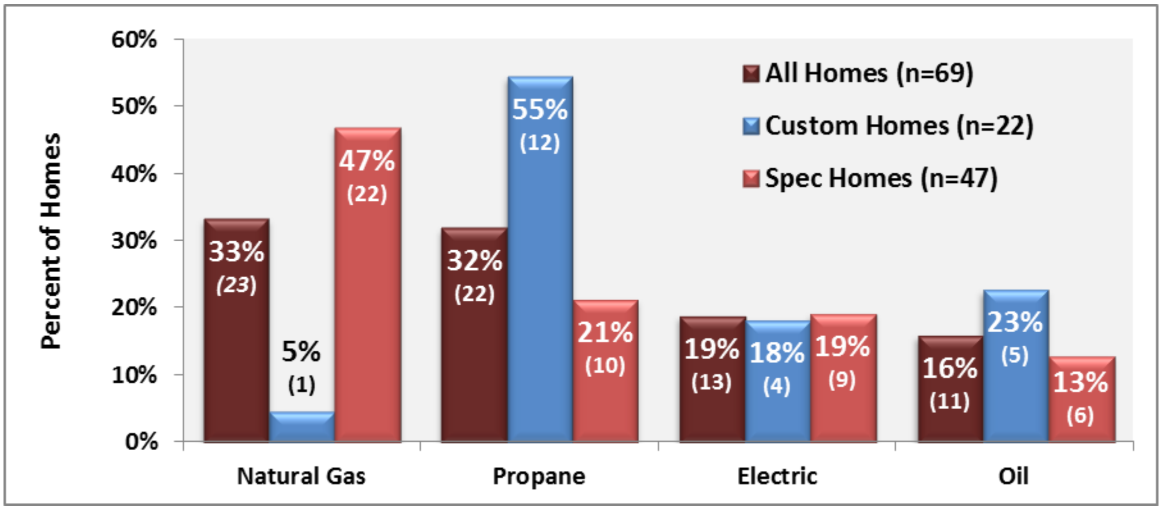
**Figure 8-11: Water Heating Systems***




*Number of homes in parentheses.

Figure 8-12 shows that one-third (33%) of inspected homes have natural gas water heaters, 32% have propane, 19% have electric and 16% have oil water heaters. Custom homes are much less likely than spec homes to have a natural gas water heater (5% versus 47%) and much more likely to have a propane water heater (55% versus 21%); these differences are statistically significant at the 90% confidence level.

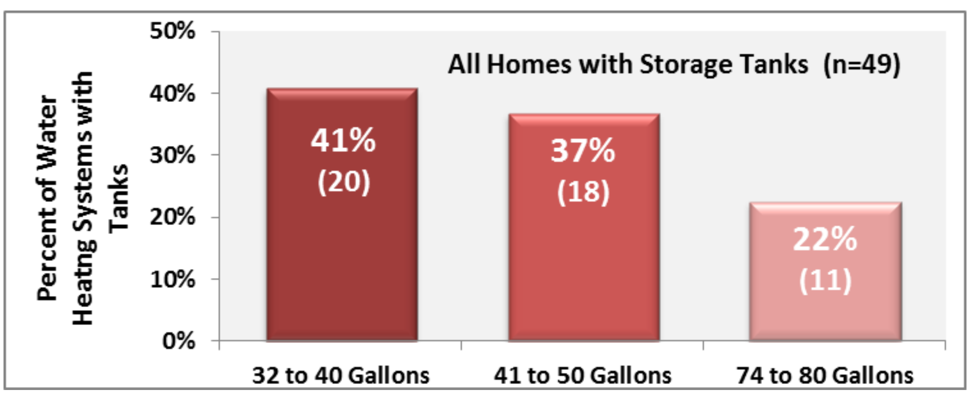
**Figure 8-12: Water Heating Fuel***




*Number of homes in parentheses.

Most inspected homes (49 out of 69 homes) have water heating systems with storage tanks. The most common tank sizes are 40 gallons (39%) and 50 gallons (33%). Figure 8-13 shows that 41% of homes have 32 to 40 gallon tanks, 27% have 41 to 50 gallon tanks, and 22% have 74 to 80 gallon tanks. Water heater tank sizes are similar for custom and spec homes.

**Figure 8-13: Water Heating Tank Size***




*Number of homes in parentheses.

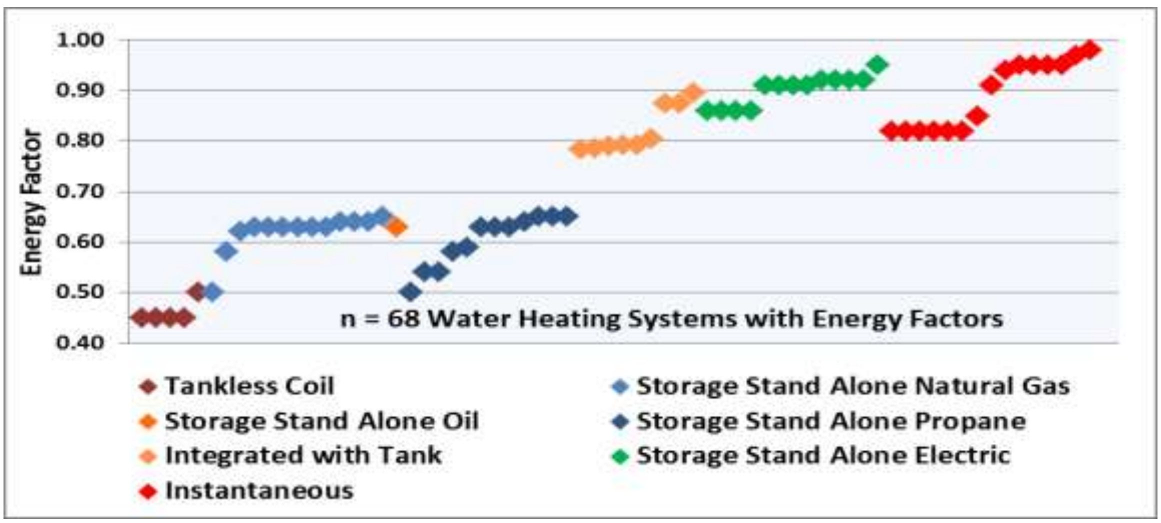
Water heater Energy Factors vary widely depending on the type of system. Energy Factors of natural gas and propane conventional storage tank systems, the most common type of system found in inspected homes, include estimated Energy Factors for four large conventional storage tank water heating systems that are not FVIR (Flammable Vapor Ignition Resistant)[39] construction and do not have reported Energy Factors: Energy Factors for these four water heaters were estimated using the RESNET Energy Factor Calculator for Commercial DHW Tanks.[40] Of the water heaters eligible for ENERGY STAR qualification (instantaneous and high-efficiency gas storage) 80% (33 of 41 water heaters) are ENERGY STAR-qualified. Table 8-12 shows that conventional electric storage tank water heating systems have the highest average Energy Factor (0.90 EF), followed by instantaneous (0.89 EF), indirect[41] (average 0.82 EF), conventional fossil-fuel fired water heaters (average 0.61 EF), and tankless coil water heating systems, the least efficient (average 0.46 EF).[42]

**Table 8-12: Water Heating Energy Factor Statistics**

| Water Heating Energy Factor | Conventional Fossil-Fuel Fired (n=26 ) | Instantaneous (n=15 homes) | Conventional Electric (n=13 homes) | Indirect with Tank (n=9) | Tankless Coil (n=5) |
|---|---|---|---|---|---|
| Minimum | 0.50 | 0.82 | 0.86 | 0.78 | 0.45 |
| Maximum | 0.65 | 0.98 | 0.95 | 0.90 | 0.5 |
| **Average** | **0.61** | **0.89** | **0.90** | **0.82** | **0.46** |
| Median | 0.63 | 0.91 | 0.91 | 0.79 | 0.45 |

Figure 8-14 graphs the water heating system Energy Factors for the 64 systems for which Energy Factors are available.

**Figure 8-14: Water Heater Energy Factors by Type of System**




[39] Flammable Vapor Ignition Resistance 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

[40] http://www.resnet.us/uploads/documents/standards/Commercial_Hot_Water_EF_Calculator_12-10.xls

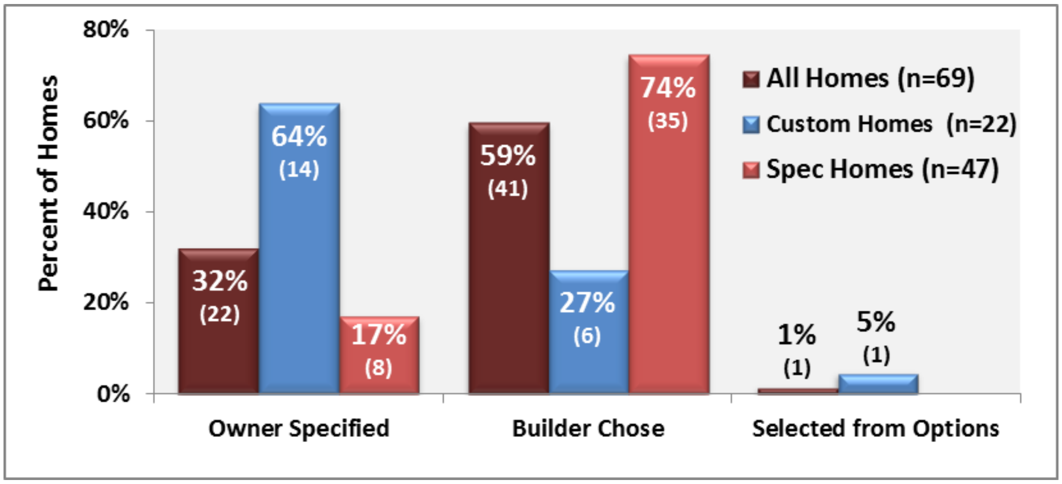
[41] Energy Factors for integrated tank systems are calculated as 92% of the boiler AFUE.

[42] Consistent with the NE-HERS manual, the Energy Factor for tankless coil water heating systems is estimated based on occupancy: 0.45 for three occupants, 0.50 for four occupants, .0.55 for five occupants and 0.60 for six occupants.

### *8.5.1 Who Specified Water Heaters*

The on-site homeowner survey asked who specified the water heater. Figure 8-15 shows that 32% of all homeowners say they specified the water heater for their home. Owners of custom homes were more than three times as likely to say they specified water heater (64%) than owners of spec homes (17%); this difference is statistically significant at the 90% confidence level. Owners of spec homes were much more likely to say the builder chose the water heater (74%) than owners of custom homes (27%); this difference is statistically significant at the 90% confidence level.

**Figure 8-15: Who Specified Water Heater***




*Number of homes in parentheses.

Homeowners were asked if they remembered what they specified. Of the 22 homeowners who say they specified the water heater for their home, 16 identified at least one thing they specified:

- Three homeowners say they specified the water heating fuel.
- Eight homeowners say they specified the type of water heater.
- Eight homeowners say they specified an energy-efficient water heater.

Only four of the eight homeowners who say they specified an energy-efficient water heater say they specified an ENERGY STAR-labeled water heater; two of these homeowners have ENERGY STAR-qualified water heaters (one instantaneous and one propane conventional tank) and two have boiler heating systems with an integrated storage tank for hot water. Of the four homeowners who specified an energy-efficient water heater, but not an ENERGY STAR-labeled water heater, three have ENERGY STAR-labeled instantaneous water heaters and one has a boiler heating system with an integrated storage tank for hot water.

Table 8-13 shows who specified the water heater by the type of water heater observed in the inspected homes and the percent of ENERGY STAR-qualified water heaters. As shown, homeowners who say they specified the water heater in their home were most likely to specify an instantaneous water heater (36%), over three times as likely as builders (10%); this difference is statically significant at the 90% confidence level. All the instantaneous water heaters specified by owners and builders are ENERGY STAR-qualified. Builders were most likely to specify a conventional gas water heater (51%) compared to only 18% of homeowners who say they specified their water heater; this difference is statistically significant at the 90% confidence level. Conventional gas water heaters specified by builders were more likely to be ENERGY STAR-qualified than conventional gas water heaters specified by home owners, 71% of those specified by builders compared to 50% of those specified by homeowners, but this difference is not statistically significant.

**Table 8-13: Who Specified Water Heater by Type of Water Heater**

| Type of Water Heater System | Builder Chose (n=41 Homes) | | Owner Specified (n=22 Homes) | |
|---|---|---|---|---|
| | Number & Percent of Water Heaters | Percent ENERGY STAR Water Heaters | Number & Percent of Water Heaters | Percent ENERGY STAR Water Heaters |
| **Instantaneous** | 4 **(10%)*** | 100% | 8 **(36%)*** | 100% |
| **Electric Conventional Storage Tank** | 5 (17%) | n/a | 5 (23%) | n/a |
| **Gas Conventional Storage Tank** | 21 **(51%)*** | 71% | 4 **(18%)*** | 50% |
| **Boiler with Integrated Tank** | 4 (10%) | n/a | 4 (18%) | n/a |
| **Tankless Coil** | 4(10%) | n/a | 1 (5%) | n/a |
| **Oil Conventional Storage Tank** | 1 (2%) | n/a | 0 | n/a |

* Significantly different at the 90% confidence level.

## *8.6 Mechanical Ventilation*

Auditors recorded information on mechanical ventilation during the on-site inspections. Under both 2006 and 2009 IECC the requirements for mechanical ventilation are the same. The codes state that, "Outdoor air intakes and exhausts shall have automatic or gravity dampers that close when the ventilation system is not operating." Auditors did not collect information on dampers; rather they collected information on any equipment being used as mechanical ventilation. 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 five of the audited homes have mechanical ventilation; one home has a heat recovery ventilation system (HRV), one home has a whole house attic fan that is thermostatically controlled, one home has a bathroom fan on a timer, and the other two homes have integrated bathroom fans.[43]

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 HRV found onsite exhausts at various rates ranging from 86 CFM to 207 CFM. The sensible recovery efficiency for this unit ranges from 61% to 64% depending on the outside air temperature and exhaust rate.[44]

Including the five homes with mechanical ventilation, 68 out of the 69 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, among the 68 homes with bathroom fans, auditors counted 144 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.

[43] Integrated bathroom fans have a humidity sensor that automatically powers the fan.
[44] The sensible recovery efficiency is the efficiency with which sensible heat is transferred between the supply and exhaust air flows of the HRV.

# 9 Ducts

## 9.1 Mandatory Duct Insulation Requirements

Under 2006 IECC it is a mandatory requirement that ducts located in unconditioned space have a minimum of R-8 insulation. During the 64 site visits at homes with ducts, KEMA raters identified R-8 insulation or higher on ducts located in unconditioned space less than half of the time. Moreover, only 14 (23%) of the 62 homes with ducts located in unconditioned space met 2006 IECC mandatory duct insulation requirements by having all of the ducts (supply and return) in unconditioned spaces insulated to R-8 or higher.[45] Under 2009 IECC, duct insulation requirements were relaxed. Under 2009 IECC it is a mandatory requirement that ducts located in unconditioned space have a minimum of R-6 insulation. The 2009 IECC prescriptive path requires supply ducts located in attics to be insulated to R-8, while all other ducts located in unconditioned space must be insulated to R-6. Thirty-six (58%) of the 62 homes with ducts located in unconditioned space have at least R-8 supply attic duct insulation and all other ducts located in unconditioned space insulated to at least R-6. As shown in Table 9-1, the average R-value of duct insulation calculated over all types of ducts in all unconditioned locations is R-7.1. The average R-value for spec homes (R-7.0) is lower than the average R-value for custom homes (R-7.6) and this difference is statistically significant at the 90% confidence level.

**Table 9-1: Duct Insulation Statistics**

| Duct Insulation Level<br>All Ducts in Unconditioned Spaces | Homes with Ducts in Unconditioned Space (n=62) |
|---|---|
| **Comparison to 2006 IECC Mandatory Requirement of R-8** | |
| **Less than R-8** | 48 (77%) |
| **R-8** | 10 |
| **More than R-8** | 4 |
| **Comparison to 2009 IECC Prescriptive Requirement (Supply-Attic R-8, All Other R-6)** | |
| **Less than Supply-Attic R-8, All Other R-6** | 26 |
| **Supply-Attic R-8, All Other R-6** | 10 |
| **More than Supply-Attic R-8, All Other R-6** | 26 |
| **R-value Statistics** | |
| **Minimum R-value** | 0.0 |
| **Maximum R-value** | 10.5 |
| **Average R-value** | **7.1** |
| **Median R-value** | 7.0 |

[45] 2006 IECC makes an exception for ducts located in floor trusses, which only need to be insulated to R-6. However, auditors did not collect data specific to ducts in floor trusses and therefore assumed non-compliance if duct insulation was less than R-8.

## 9.2 Homes with Ducts

The majority of the inspected homes (64 out of 69) have ductwork. Only two homes have all ducts installed in conditioned space; an additional nine homes have some ducts installed in conditioned space. Table 9-2 shows the various heating and cooling system combinations in the inspected homes. The majority of homes (43 or 62%) have a furnace and central air conditioning; this combination is over three times as common in spec homes than custom homes (38 out of 47 spec homes versus 5 out of 22 custom homes). The next most common combination is a hot water boiler with central air conditioning (11 homes). The five homes with no ductwork have a hot water boiler without central air conditioning. An additional five homes have a furnace without central air conditioning; three homes have a hydro-air boiler with central air conditioning; one has a ground source heat pump; and one has a dual purpose water heater with central air conditioning.

**Table 9-2: Mechanical Equipment**

| Heating/Cooling System Combination | All Homes (n=69) |
|---|---|
| Furnace with Central Air Conditioning | 43 (62%) |
| Boiler (hot water) with Central Air Conditioning | 11 |
| Furnace without Central Air Conditioning | 5 |
| Boiler (hot water) without Central Air Conditioning | 5 |
| Boiler (hydro-air) with Central Air Conditioning | 3 |
| Ground Source Heat Pump Heating & Cooling | 1 |
| Dual Purpose Water Heater with Central Air Conditioning | 1 |

## 9.3 Duct Insulation R-values

Table 9-3 shows the average R-value of duct insulation for supply and return ducts in unconditioned space by location. The 2006 IECC requires minimum R-8 insulation for all ducts (supply and return) in unconditioned space; 2009 IECC standard requires supply ducts in attics to be insulated to R-8; all other ducts located in unconditioned space must be insulated to R-6. As shown, the average R-value for supply ducts is higher than for return ducts. This is due in part to return ducts more often being uninsulated; out of the five homes with uninsulated ducts in unconditioned space, all have uninsulated return ducts and one home has uninsulated supply ducts.

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

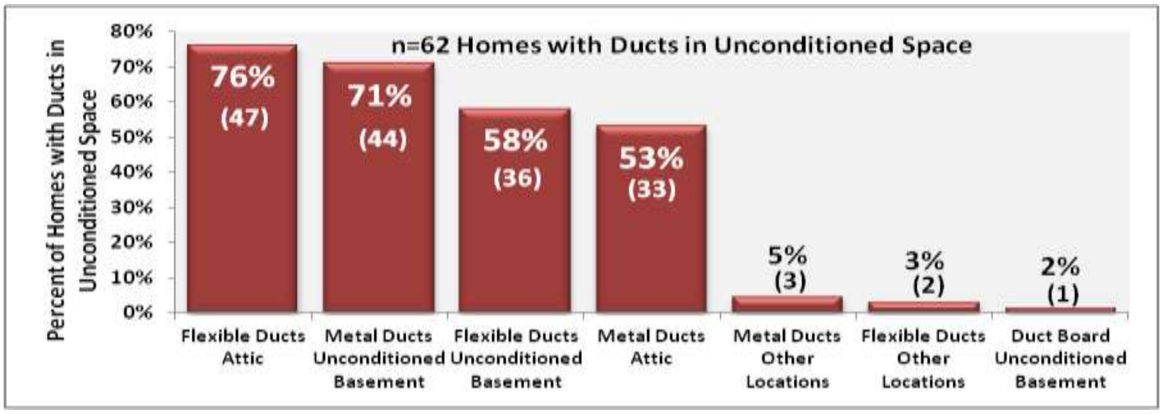
| Duct Location | All Homes with Ducts in Unconditioned Space (n=62) | |
|---|---|---|
| | Average Supply Duct R-value | Average Return Duct R-value |
| Attic (n=51) | 7.7 | 7.4 |
| Unconditioned Basement (n=46) | 7.2 | 6.2 |
| Other* (n=4) | 5.3 | 6.9 |
| Average R-value Over All Ducts in Unconditioned Locations | | |
| All Ducts in Unconditioned Space | 7.4 | 6.8 |

* Refers to unconditioned spaces other than unconditioned basements and attics.

## 9.4 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 number of all homes with ducts in unconditioned space that have metal, flexible or duct board ducts in unconditioned basements, attics or other locations.[46] Homes typically have a mix of metal and flexible ducts. As shown, 47 (or 76%) of the homes with ducts in unconditioned space have at least some flexible ducts in the attic, 44 homes (or 71%) have metal ducts in an unconditioned basement, 36 homes (or 58%) have flexible ducts in an unconditioned basement, and 33 homes (or 53%) have metal ducts in the attic. Auditors did not observe panned joists in any of the homes.

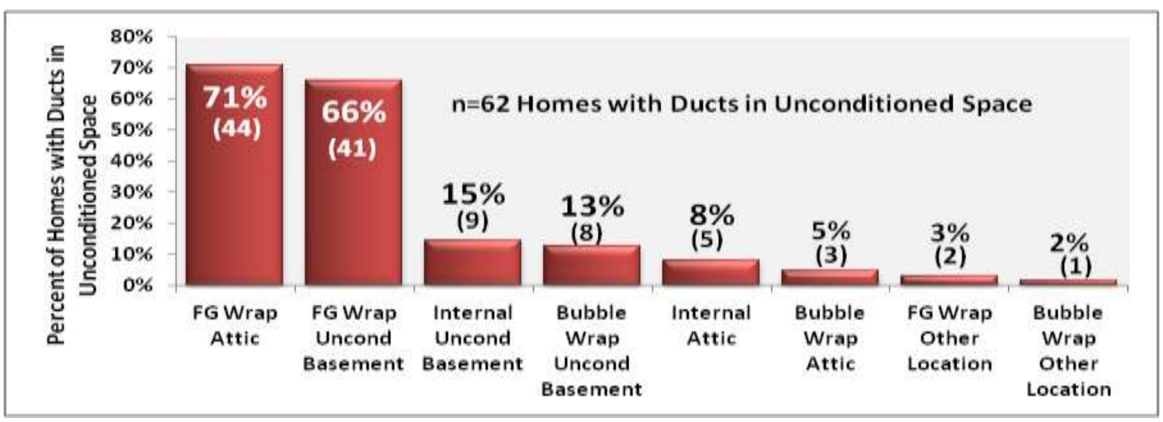
**Figure 9-1: Duct Type by Location***




*Number of homes in parentheses.

Figure 9-2 shows the type of duct insulation by location for all homes with ductwork in unconditioned space. Fiberglass wrap is the most commonly observed type of duct insulation. As shown, 44 (or 71%) of the homes with ducts in unconditioned space have attic ducts insulted with fiberglass wrap and 41 homes (or 66%) have ducts in unconditioned basements insulated with fiberglass wrap.

**Figure 9-2: Duct Insulation Type by Location***




*Number of homes in parentheses.

[46] Other locations include crawl spaces and garages.

Several instances of bubble wrap insulation were observed in unconditioned basements and attics. The use of bubble wrap product to insulate ducts is somewhat controversial in the building industry because critics claim that the actual R-value of this material is approximately R-1.0 based on ASTMC518 testing. Auditors used the manufacturer rated R-values, which can vary based on installation practices. The reported R-values ranged from R-4.2 to R-10.3.

Uninsulated ducts in unconditioned space were observed in five homes: four homes have uninsulated ducts in an unconditioned basement and one home has uninsulated ducts in an unconditioned garage. All five homes in which uninsulated ducts were observed in unconditioned space are spec homes.

## 9.5 Duct Leakage

The 2006 IECC does not have a duct leakage requirement, but the 2009 IECC has a mandatory requirement of 8 or less CFM25 per 100 sq. ft. of conditioned floor area for ducts tested post construction. Only six homes meet the 2009 IECC requirement—two custom and four spec homes.

As discussed earlier, 64 of the 69 homes inspected have duct systems and in two of these homes all ducts are installed in conditioned space. Auditors were able to conduct duct leakage tests at 61 of the 64 homes with ducts.

Auditors were unable to test ducts in three homes for the following reasons:

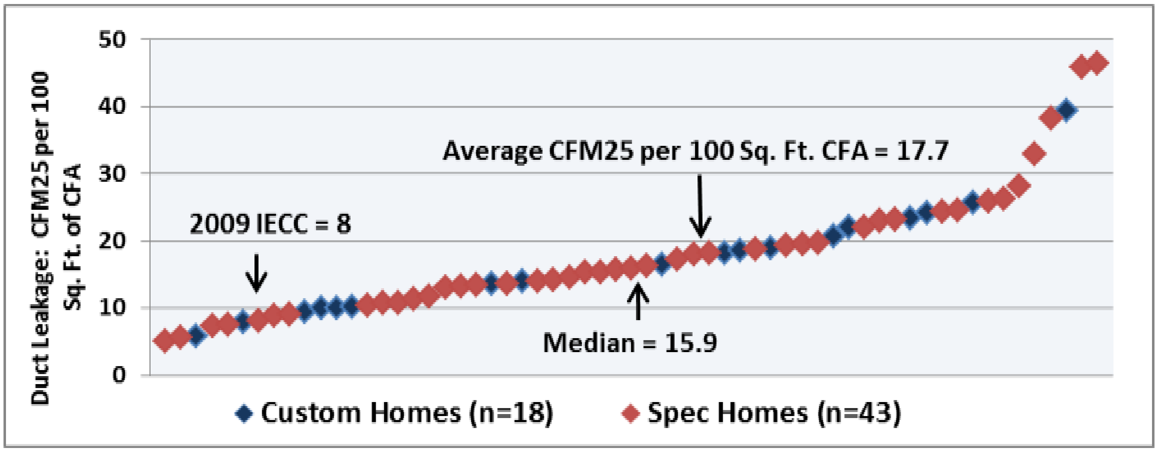
- Homeowner refused
- The furnace was suspended from the ceiling of the garage and the ductwork for the attic air conditioning system was entirely in conditioned space.
- The homeowner informed the auditors that the home had mold and vermin issues that were being treated.

Table 9-4 shows duct leakage to the outside ranged from 5.0 to 46.4 CFM25 per 100 sq. ft. of conditioned floor area. The overall average is 17.7 CFM25 per 100 sq. ft. of conditioned floor area. The average for custom homes is 17.1 and the average for spec homes is l8.0; this difference is not statistically significant at the 90% confidence level. Figure 9-3 shows duct leakage by home.

**Table 9-4: Duct Leakage Statistics**

| Duct LeakageCFM25 per 100 Sq. Ft. Conditioned Floor Area | All Homes (n=61) |
|---:|---|
| **Minimum** | 5.0 |
| **Maximum** | 46.4 |
| **Average** | **17.7** |
| **Median** | 15.9 |

**Figure 9-3: Duct Leakage by Home**




Putting duct leakage results into perspective, 17 CFM25 per 100 sq. ft. of conditioned floor area is:

- More than double the 2009 IECC mandatory requirement of 8 or less CFM25 per 100 sq. ft. of conditioned floor area for ducts tested post construction (6 inspected homes had 8 or less CFM25 per 100 sq. ft. of conditioned floor area)
- 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 (no inspected homes had 4 or less CFM25 per 100 sq. ft. of conditioned floor area)

It is impossible to predict how much impact the 2009 IECC may have on duct leakage levels in new homes in Connecticut. In a 2011 Massachusetts Baseline Study of Single-family Residential New Construction,[47] auditors conducted duct leakage tests at 69 homes. All homes inspected in the 2011 Massachusetts Baseline Study were permitted under 2009 IECC. In addition, in a separate study, Massachusetts conducted duct leakage testing at 40 homes built at the end of the 2006 IECC cycle.[48] Average duct leakage was lower in the 2009 IECC homes (12.4 average CFM25 per 100 sq. ft. of conditioned floor area) than in the 2006 IECC homes (average 17.2 CFM25 per 100 sq. ft. of conditioned floor area) and this difference is statistically significant at the 90% confidence level. Average duct leakage for the 40 Massachusetts homes completed at the end of the 2006 IECC cycle is almost identical to average duct leakage for the 61 Connecticut baseline homes completed at the end of the 2006 IECC cycle. This suggests Connecticut may want to consider using a duct leakage UDRH input going forward that is lower than the 17.7 CFM25 per 100 sq. ft. of conditioned floor area reported for homes completed at the end of the 2006 cycle in Connecticut if there are reasons

[47] Massachusetts 2011 Baseline Study of Single-family Residential New Construction, Final Report, Submitted to Berkshire Gas, Cape Light Compact, Columbia Gas of Massachusetts, National Grid, New England Gas Company, NSTAR Electric & Gas, Unitil, and Western Massachusetts Electric Company by NMR Group, Inc. KEMA, Inc. and Dorothy Conant. August 2012.

[48] Massachusetts Mini Baseline Study of Homes Built at the End of the 2006 IECC Cycle, Final Report, Submitted to Massachusetts Residential New Construction Program Administrators by NMR Group, Inc. KEMA, Inc. and Dorothy Conant. June 2012.

to assume the same trend toward lower duct leakage in 2009 IECC homes is likely to occur in Connecticut. However, it should be noted that another New England state studied average duct leakage in 22 homes permitted under 2009 IECC. That study found average duct leakage was 18.9 CFM25 per 100 sq. ft. of conditioned floor area, which is higher than the average duct leakage for Connecticut baseline homes completed at the end of the 2006 IECC cycle.

# 10 Air Infiltration

There are no specific air infiltration measurement requirements under either the 2006 or 2009 IECC prescriptive paths. However, both 2006 and 2009 IECC require determining whether or not a home meets air sealing requirements via visual inspection. Under 2009 IECC, air sealing can be considered compliant via blower door testing if air changes per hour measured at 50 Pascals (ACH50) is 7 or lower. Overall, 54 of 69 homes (78%) have 7 or lower ACH50; 15 of 22 custom homes (68%) and 39 of 47 spec homes (83%). The ENERGY STAR Version 3 performance path requires air infiltration to be 4 ACH50 or lower; 19% of the inspected homes have 4 or lower ACH50; 27% of custom and 15% of spec homes.

Auditors conducted blower door tests on all 69 inspected homes. 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 (ACH50) and heating season, cooling season, and average natural air changes per hour (ACHnat) from REM/Rate files. ACH50 in inspected homes ranges from 3.0 to 13.1; the average ACH50 is 5.8. Heating season ACHnat in inspected homes ranges from 0.16 to 0.78; the average heating season ACHnat is 0.33. Cooling season ACHnat in inspected homes ranges from 0.12 to 0.58; the average cooling season ACHnat is 0.25, and average ACHnat is 0.29. Average ACH50 and ACHnat are slightly higher for custom homes than spec homes, but the differences are not statistically significant at the 90% confidence level.

**Table 10-1: Air Infiltration Statistics**

| Air Infiltration ACH50 & ACHnat | ACH50 All Homes (n=69) | ACHnat Heating Season All Homes (n=69) | ACHnat Cooling Season All Homes (n=69) | Average ACHnat All Homes* (n=69) |
|---|---|---|---|---|
| Minimum | 3.0 | 0.16 | 0.12 | 0.14 |
| Maximum | 13.1 | 0.78 | 0.58 | 0.68 |
| **Average** | **5.8** | **0.33** | **0.25** | **0.29** |
| Median | 5.6 | 0.32 | 0.23 | 0.28 |

*Average ACHnat air infiltration is the average of the heating season and cooling season ACHnat values calculated in the REM/Rate files.

Figure 10-2 graphs ACH50 by home.

**Figure 10-1: Air Changes per Hour (ACH50) by Home**

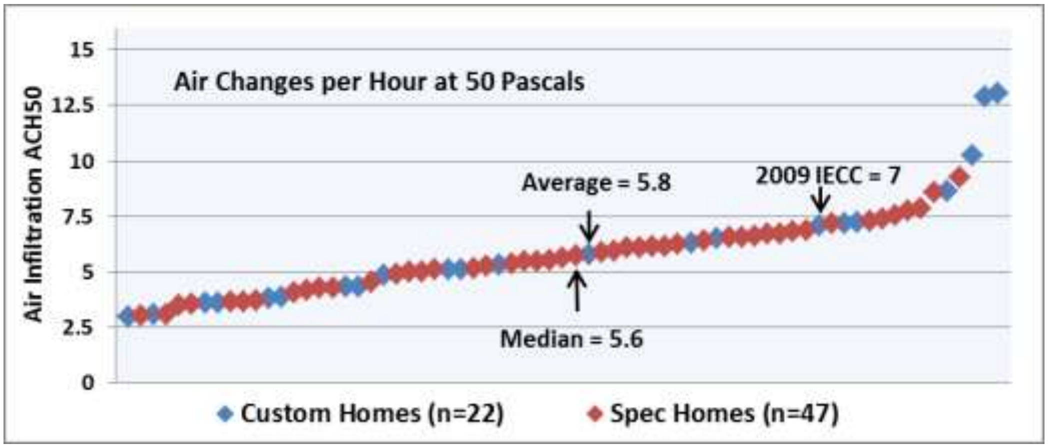
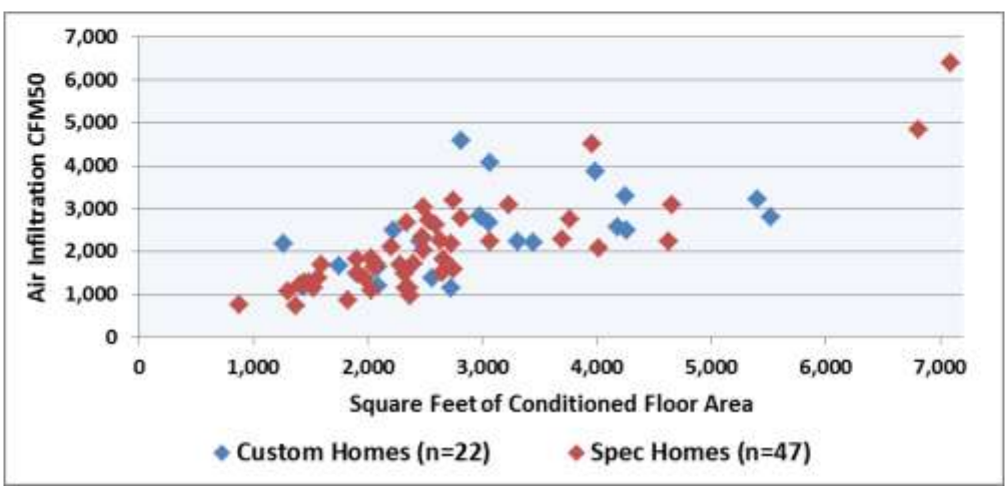



Table 10-2 shows average CFM50 for the 69 inspected homes ranges from 729 to 6,395; the average is 2,179 and the median is 2,084 CFM50. Average CFM50 for custom homes is 2,430 and the average for spec homes is lower, at 2,061 CFM50; this difference is not statistically significant at the 90% confidence level. Figure 10-2 shows total CFM50 by home size. As shown, total leakage varies widely for homes of similar size.

**Table 10-2: Total CFM50 Leakage Statistics**

| Total CFM50 | All Homes (n=69) |
|---|---|
| **Minimum CFM50** | 729 |
| **Maximum CFM50** | 6,395 |
| **Average CFM50** | **2,179** |
| **Median CFM50** | 2,084 |

**Figure 10-2: Total CFM50 Leakage by Home Size**



## *10.1 Air Infiltration and Type of Insulation*

Thirty percent of inspected homes (21 homes) have something other than fiberglass batt wall and/or ceiling insulation; all floor insulation in inspected homes is fiberglass batts. The manufacturers and installers of advanced forms of insulation tout their products as providing superior performance because they reduce both convective losses (i.e., reduce air leakage) and conductive losses. Table 10-3 shows that average ACH50 is lower in homes that use something other than fiberglass batts in at least some wall and or ceiling areas. The difference between ACH50 in homes that use only fiberglass batt insulation (6.2 ACH50) versus homes that use something other than fiberglass batts (5.1 ACH50) is statistically significant.

**Table 10-3: Air Infiltration by Type of Wall and Ceiling Insulation**

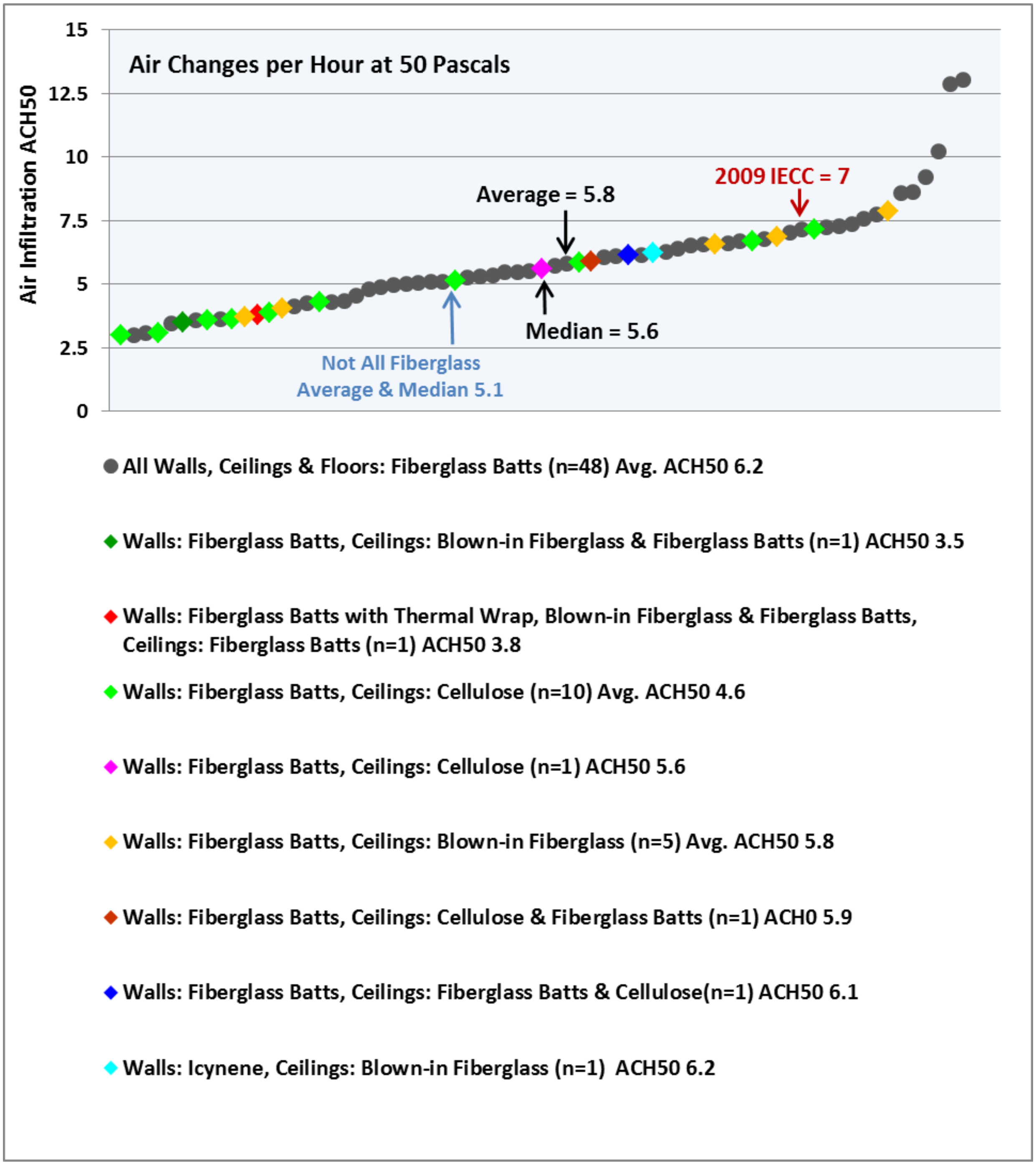
| Air Infiltration ACH50 | All Homes (n=69) | Homes All Fiberglass Wall & Ceiling Insulation (n=48) | Homes with Non-Fiberglass Batt Wall & Ceiling Insulation (n=21) |
|---|---|---|---|
| **Minimum** | 3.0 | 3.0 | 3.0 |
| **Maximum** | 13.1 | 13.1 | 7.9 |
| **Average** | **5.8** | **6.2*** | **5.1*** |
| **Median** | 5.6 | 5.8 | 5.1 |

*Significantly different at the 90% confidence level.

Figure 10-3 on the next page charts ACH50 by home with the homes that have something other than only fiberglass batt wall and/or ceiling insulation identified. As shown, ten homes have fiberglass batt wall and cellulose ceiling insulation and five homes have fiberglass batt wall and blown-in fiberglass ceiling insulation. Six homes have the following unique insulation combinations:

- Walls: Fiberglass Batts with Thermal Wrap, Blown-in Fiberglass & Fiberglass Batts, Ceilings: Fiberglass Batts ACH50 3.8
- Walls: Fiberglass Batts, Ceilings: Blown-in Fiberglass & Fiberglass Batts ACH50 3.5
- Walls: Fiberglass Batts, Ceilings: Cellulose & Fiberglass Batts ACH0 5.9
- Walls: Fiberglass Batts, Ceilings: Cellulose ACH50 5.6
- Walls: Fiberglass Batts, Ceilings: Fiberglass Batts & Cellulose ACH50 6.1
- Walls: Icynene, Ceilings: Blown-in Fiberglass ACH50 6.2

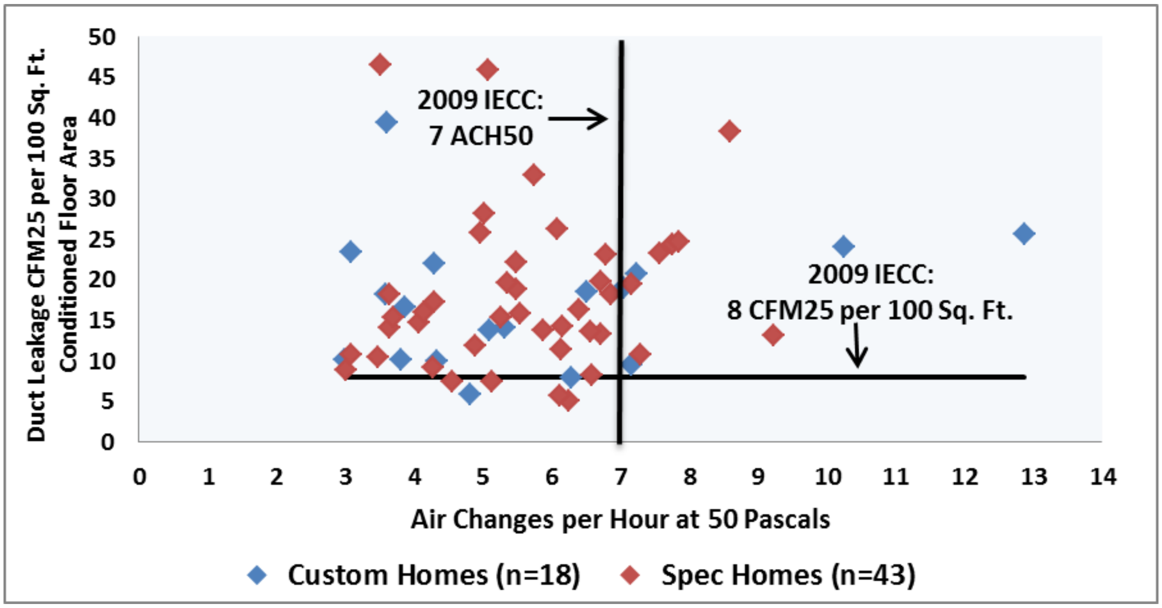
**Figure 10-3: Air Infiltration by Type of Wall and Ceiling Insulation**



## 10.2 Air Infiltration and Duct Leakage

Many tight homes have leaky ducts. Figure 10-4 shows air infiltration and duct leakage levels for the 61 inspected homes with both air infiltration and duct leakage data. Only 10% of the homes (6 homes lower left), meet 2009 IECC requirements for both duct leakage and air infiltration. Over two-thirds (70%) of the homes (43 homes upper left) meet the 2009 IECC air infiltration requirement but not the duct leakage requirement. One-fifth (20%) of the homes (12 homes upper right) do not meet the 2009 IECC duct leakage or air infiltration requirements. No homes (lower right) meet the 2009 IECC duct leakage requirement, but not the air infiltration requirement.

**Figure 10-4: Air Infiltration and Duct Leakage**



# 11 Lighting

Auditors collected information on the total number of fixtures and ceiling fans and types of light bulbs (including fluorescent tubes) in each fixture in each home. In addition to establishing a baseline, these data were used to determine that only 3 of the 69 homes visited would have met the 2009 IECC prescriptive requirement to have a minimum of 50 percent of the lamps in permanently installed lighting fixtures be high-efficacy lamps. The 2006 IECC has no lighting requirement.

It is impossible to predict how much impact the 2009 IECC may have on the level of energy-efficient lighting in new homes in Connecticut. However, a comparison of the results of two recently completed Massachusetts residential new construction baseline studies, one that inspected 50 homes[49] completed at the end of the 2006 IECC and another that inspected 100 homes[50] permitted under 2009 IECC, showed no increase in the level of energy-efficient lighting installed in 2009 IECC homes. Therefore, we believe the study findings on lighting in Connecticut homes completed at the end of the 2006 IECC cycle are a reasonable baseline.

## *11.1 Lighting Counts from the On-Site Inspections*

Auditors counted the number of permanently attached fixtures containing: screw-in CFL bulbs, pin-based CFL bulbs, LED bulbs, fluorescent tubes, and incandescent bulbs in each home. For the purposes of this analysis, the first four are considered energy efficient.[51] Fifty-two out of 69 or three-quarters (75%) of the homes visited have very few fixtures with energy-efficient bulbs installed, accounting for 10% or less of all fixtures installed in the home. Only three of the 69 homes visited have 50% or more of their fixtures with bulbs classified as energy efficient and would have met the prescriptive path lighting standard for 2009 IECC; all three of these homes were spec built.[52] (Table 11-1)

[49] Massachusetts Mini Baseline Study of Homes Built at the End of the 2006 IECC Cycle, Final Report, Submitted to Massachusetts Residential New Construction Program Administrators by NMR Group, Inc. KEMA, Inc. and Dorothy Conant. June 2012.

[50] Massachusetts 2011 Baseline Study of Single-family Residential New Construction, Final Report, Submitted to Berkshire Gas, Cape Light Compact, Columbia Gas of Massachusetts, National Grid, New England Gas Company, NSTAR Electric & Gas, Unitil, and Western Massachusetts Electric Company by NMR Group, Inc. KEMA, Inc. and Dorothy Conant. August 2012.

[51] It is important to note here that the auditors only counted fixtures; there may well be homes with plug-in lamps that contain CFL bulbs which are not reflected in the analyses presented in this chapter.

[52] The analysis assumes that the proportion of energy-efficient fixtures would be equal to the proportion of energy efficient bulbs or lamps installed in the home.

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

| Percent of Fixtures with Energy-Efficient Bulbs in the Home | All Homes (n=69) |
|---|---|
| 10% or less | 52 (75%) |
| 11% to 30% | 10 |
| 30% to 49% | 4 |
| Met 2009 IECC Standard (50% or more energy-efficient fixtures) | |
| 50% to 79% | 1 |
| 80% to 100% | 2 |

A similar analysis was performed for each home based on whether the builder or home owner chose the fixtures installed. As Table 11-2 shows, builders and owners chose to install similar proportions of fixtures with energy-efficient bulbs; the difference is not statistically significant, at the 90% confidence level.

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

| Percent of Fixtures with Energy-Efficient Bulbs in the Home | All Homes (n=69) | Builder Chose Fixtures (n=28) | Owner Chose Fixtures (n=41) |
|---|---|---|---|
| 10% or less | 52 (75%) | 20 (72%) | 32 (78%) |
| 11% to 30% | 10 | 3 | 7 |
| 30% to 49% | 4 | 3 | 1 |
| Comparison with 2009 IECC (50% or more energy-efficient fixtures) | | | |
| 50% to 79% | 1 | 1 | 0 |
| 80% to 100% | 2 | 1 | 1 |

Looking at the total number of fixtures counted in visited homes, only an average of 10% of fixtures per home contain energy-efficient bulbs.[53] Custom homes, which have an average of 408 more square feet of conditioned floor area than spec homes, have an average of 9 more fixtures than spec homes, but the percentage of fixtures with energy-efficient bulbs is almost the same.[54] All homes have an average of 4.4 fixtures containing energy-efficient bulbs, but the median is only 1.0 fixture containing energy-efficient bulbs because relatively few homes account for the bulk of fixtures with energy-efficient bulbs installed. (Table 11-3)

**Table 11-3: Types of Fixtures Installed—All Homes**

| Number of Fixtures by Type of Bulb Installed in All Homes | All Homes (n=69) |
|---|---|
| Average number of fixtures containing screw-in or pin-based CFL bulbs | 2.8 |
| Average number of fixtures containing LED bulbs | 0.2 |
| Average number of fluorescent tube fixtures | 1.4 |
| Average number of fixtures containing energy-efficient bulbs | 4.4 |
| Median number of fixtures containing energy-efficient bulbs | 1.0 |
| Average number of total fixtures | 47.2 |
| Average percent of fixtures containing energy-efficient bulbs | 10% |

The analysis was rerun to exclude 33 homes that had only fixtures with incandescent bulbs installed. When looking at the 36 homes that had at least one fixture with energy-efficient bulbs installed, the average percentage of fixtures containing energy-efficient bulbs per home is higher at 19%. (Table 11-4)

**Table 11-4: Types of Fixtures Installed—Homes with One or More Fixture Containing Energy-Efficient Bulbs**

| Number of Fixtures by Type in Homes with Any Fixtures that Contain Energy-Efficient Bulbs | All Homes (n=36) |
|---|---|
| Average number of fixtures containing screw-in or pin-based CFL bulbs | 5.3 |
| Average number of fixtures containing LED bulbs | 0.4 |
| Average number of fluorescent tube fixtures | 2.8 |
| Average number of fixtures containing energy-efficient bulbs | 8.4 |
| Median number of fixtures containing energy-efficient bulbs | 5.0 |
| Average number of total fixtures | 51.3 |
| Average percent of fixtures containing energy-efficient bulbs | 19% |

[53] This study calculates the percentages of fixtures containing energy efficient bulbs as the averages found in the homes visited rather than simply looking at all fixtures containing energy efficient bulbs as a percentage of all fixtures. The methodology used in this study is preferred in lighting saturation studies as it prevents a few homes with a large number of fixtures containing energy efficient bulbs from skewing the results.
[54] The average custom home is 3,036 square feet and the average spec home is 2,628 square feet.

Table 11-5 summarizes saturation of fixtures containing energy-efficient bulbs by room type. Because not every home contains the same room types, saturations were calculated based only on those homes where the room type was present. It is important to note that the on-site inspections were designed to collect information on the total number of fixtures based on bulb type but did not collect bulb counts. When interpreting data presented in the table below bear in mind that one fixture may contain a single bulb or multiple bulbs and, as such, fixture counts do not represent bulb counts. For example, kitchen fixtures are often recessed cans with one bulb per fixture, while dining rooms or foyers are more likely to have a lighting fixture with multiple bulbs. In addition, due to the relatively low number of homes for which there is data available for some room types the reader should exercise caution in drawing conclusions about the portion of fixtures with energy-efficient bulbs in particular types of rooms.

It is worth noting that fixtures found in closets (27%) and laundry rooms (23%) are the most likely to contain energy-efficient bulbs—about one in four. In contrast, fixtures found in family rooms (6%), dens (4%) and dining rooms (3%) are the least likely to contain energy-efficient bulbs. There is thus some evidence that the most energy-efficient bulbs are installed in relatively low use areas.

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

| Rooms | Number of Homes | Average Percent of Fixtures with Energy-Efficient Bulbs per Home in each Room Type | Average Number of Total Fixtures per Home in each Room Type | Average Number of Total Fixtures with Energy-Efficient Bulbs per Home in each Room Type |
|---|---|---|---|---|
| **All Rooms** | 69 | 10% | 47.2 | 4.4 |
| **Bedroom** | 69 | 10% | 8.4 | 0.7 |
| **Bathroom** | 69 | 10% | 7.9 | 0.8 |
| **Kitchen** | 68 | 10% | 7.9 | 0.8 |
| **Hallway** | 65 | 8% | 4.8 | 0.2 |
| **Living Room** | 56 | 7% | 5.0 | 0.2 |
| **Dining Room** | 49 | 3% | 2.4 | 0.1 |
| **Basement** | 38 | 10% | 8.3 | 0.7 |
| **Foyer** | 32 | 11% | 2.2 | 0.7 |
| **Utility Room** | 26 | 12% | 2.0 | 0.2 |
| **Family Room** | 25 | 6% | 4.1 | 0.2 |
| **Office** | 22 | 17% | 3.6 | 0.5 |
| **Closet** | 18 | 27% | 2.0 | 0.6 |
| **Den** | 12 | 4% | 3.2 | 0.2 |
| **Laundry** | 11 | 23% | 1.6 | 0.4 |
| **Garage** | 10 | 17% | 4.4 | 2.0 |
| **Other**[55] | 15 | 1% | 4.2 | 0.3 |
| **Attic** | 6 | 0% | 6.3 | 0.0 |

[55] Includes: Bar, Bonus Room, Breezeway, Music Room, Sewing Room, Sitting Room, Theater Room, and Play Room.

The photographs taken of all the homes audited were used to develop counts of outdoor fixtures, but cannot be used to determine if these fixtures contain energy-efficient bulbs. The number of outdoor fixtures in the 69 homes audited ranges from 3 to 15 with an average of 6.9 and a median of 7 per home. Based on a small amount of data gathered in Connecticut and neighboring states, it is safe to assume that the overwhelming majority of outdoor lighting is incandescent. In the five Connecticut homes where outdoor fixtures with energy-efficient bulbs were counted, they made up 11% of all the outdoor fixtures. However, it should be noted that energy-efficient bulbs were observed in outdoor fixtures at only one of the five Connecticut homes; this home had seven outdoor fixtures, four of which contained energy-efficient bulbs. In a neighboring state where 18 homes have outdoor lighting information collected on site, 16 sites have only incandescent bulbs and the remaining two have a majority of incandescent bulbs.

## *11.2 Ceiling Fans*

Forty-four of the 69 homes visited (64%) have at least one ceiling fan. As Table 11-6 shows, homes that have ceiling fans are most likely to have one, two, three or four; a few homes have five or more ceiling fans.

**Table 11-6: Homes with Ceiling Fans**

| Number of Ceiling Fans | All Homes (n=69) |
|---|---|
| Zero | 25 (36%) |
| One | 8 |
| Two | 13 |
| Three | 5 |
| Four | 9 |
| Five | 6 |
| Six | 0 |
| Seven | 3 |

# 12 Appliances

Auditors collected detailed information on refrigerators, both primary and secondary, dishwashers, and clothes washers.[56] Limited information was also collected for clothes dryers and cooking ranges. There are no appliance requirements for 2006 IECC or 2009 IECC standards.

## 12.1 Refrigerators

Auditors recorded refrigerator information on the ENERGY STAR status, condition, age, type, and size. Forty-nine out of 69 or more than seven out of ten primary refrigerators are ENERGY STAR. Custom homes are somewhat less likely to have ENERGY STAR refrigerators. (Table 12-1)

**Table 12-1: ENERGY STAR Status for Primary Refrigerators**

| Primary Refrigerators | All Homes (n=69) |
|---|---|
| ENERGY STAR | 49(71%) |
| Not ENERGY STAR | 20 |

As might be expected, all 69 of the primary refrigerators in the new homes inspected are considered to be in good condition. Almost all are new. Bottom freezer models are the most common accounting for 37 out of 69 or more than one-half of primary refrigerators; most of the rest are side-by-side models. Thirty-four out of 68 or one-half of primary refrigerators are 23 to 25 cubic feet with 14 being over 25 cubic feet. (Table 12-2)

**Table 12-2: Primary Refrigerator Characteristics**

| Age (n=69) | |
|---|---|
| 2 years or less | 68 (99%) |
| 3 to 7 years | 1 |
| **Type (n=69)** | |
| Bottom freezer | 37 (54%) |
| Side-by-side | 25 |
| Top freezer | 7 |
| **Size (n=68)** | |
| 16 to 19 cubic feet | 1 |
| 20 to 22 cubic feet | 19 |
| 23 to 25 cubic feet | 34 (50%) |
| Over 25 cubic feet | 14 |

[56] Some information was collected on 69 primary refrigerators, 19 secondary refrigerators, 67 clothes washers, and 64 dishwashers; there were two homes that did not have a clothes washer and five 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.

Nineteen of the sixty-nine homes visited have secondary refrigerators. Eleven of these refrigerators, or over one-half, are not ENERGY STAR. They tend to be older, smaller, and in poorer condition than primary refrigerators. Thirteen out of 18 of these refrigerators are top-freezer models. (Table 12-3)

**Table 12-3: Secondary Refrigerator Characteristics**

| ENERGY STAR Status (n=19) | |
|---|---|
| ENERGY STAR | 8 |
| Not ENERGY STAR | 11 (58%) |
| **Condition (n=19)** | |
| Good | 10 (53%) |
| Fair | 8 |
| Poor | 1 |
| **Age (n=15)** | |
| 2 years or less | 9(60%) |
| 3 to 5 years | 2 |
| 6 years to 10 years | 2 |
| 11 years or more | 2 |
| **Type (n=19)** | |
| Top freezer | 14(74%) |
| Single door | 3 |
| Bottom freezer | 1 |
| Side-by-side | 1 |
| **Size (n=17)** | |
| 15 cubic feet or less | 1 |
| 16 to 19 cubic feet | 12(71%) |
| 20 to 25 cubic feet | 4 |

## 12.2 Dishwashers

Auditors recorded dishwasher information on the ENERGY STAR status, condition, and age. Fifty-seven out of 63 or nine out of ten dishwashers are ENERGY STAR; custom homes are more likely to have ENERGY STAR dishwashers than spec-built homes. (Table 12-4) As might be expected, all 64 of the dishwashers in the new homes inspected are considered to be in good condition and almost all are new. (Table 12-5)

**Table 12-4: ENERGY STAR Status for Dishwashers**

| Dishwashers | All Homes (n=63) |
|---|---|
| ENERGY STAR | 57(90%) |
| Not ENERGY STAR | 6 |

**Table 12-5: Dishwasher Age**

| Age (n=64) | |
|---|---|
| 2 years or less | 63(98%) |
| 3 to 7 years | 1 |

## 12.3 Clothes Washers

Auditors recorded clothes washer information on the ENERGY STAR status, condition, type, and age. Forty-three out of 64, or more than two-thirds, of clothes washers in the homes audited are ENERGY STAR; custom and spec-built homes have similar proportions of ENERGY STAR clothes washers. (Table 12-6)

**Table 12-6: ENERGY STAR Status for Clothes Washers**

| Clothes Washers | All Homes (n=64) |
|---|---|
| ENERGY STAR | 43 (67%) |
| Not ENERGY STAR | 21 |

Most clothes washers are in good condition and new. Thirty-eight out of 67 or more than one-half are front load models. (Table 12-7)

**Table 12-7: Clothes Washer Characteristics**

| Condition (n=66) | |
|---|---|
| Good | 57(86%) |
| Fair | 9 |
| **Type (n=67)** | |
| Front load | 38(57%) |
| Top load | 29 |
| **Age (n=65)** | |
| 2 years or less | 55(85%) |
| 3 to 9 years | 5 |
| 10 years or more | 5 |

## 12.4 Other Appliances

Sixty of the sixty-nine homes visited have clothes dryers; the only information collected is the fuel type. Fifty-five out of the sixty clothes dryers use electricity; four use natural gas, and one uses propane.

Information on type and fuel used was collected for 68 cooking ranges; 56 out of 68 homes have combination cook top and oven ranges. Twenty-eight out of 68 or more than two out of five cooking ranges use electricity; 22 use propane and 18 use natural gas. (Table 12-8)

**Table 12-8: Cooking Range Characteristics**

| Type (n=68) | |
|---|---|
| Combination cook top and oven | 56 |
| Separate cook top and stand-alone oven | 12 |
| **Fuel (n=68)** | |
| Electricity | 28(41%) |
| Propane | 22 |
| Natural Gas | 18 |

## 12.5 ENERGY STAR Appliances and Responses to Homeowner Survey

Homeowners filled out a short survey at the time of the on-sites indicating whether they or the builder had specified the appliances in their homes. Those who checked that they had specified their appliances were also asked if they specified energy-efficient appliances and ENERGY STAR labeled appliances. As shown in Table 12-9, 53 out of 69 or more than three quarters of homeowners say they specified their appliances. Of those who specified their appliances, 23 out of 53 remember specifically specifying energy-efficient appliances and fewer still, 16, remember specifying ENERGY STAR labeled appliances.

**Table 12-9: Appliance Selection**

| Who Specified Appliances (n=69) | |
|---|---|
| Homeowner | 53(77%) |
| Builder | 14 |
| No response | 2 |
| **Specified Energy-Efficient Appliances (n=53)** | |
| Yes | 23(43%) |
| **Specified ENERGY STAR Appliances (n=53)** | |
| Yes | 16(30%) |

The data on appliance specification is compared to the portion of ENERGY STAR appliances found in Table 12-10. For all three appliances studied—primary refrigerators, dishwashers, and clothes washers—appliances specified by homeowners are more likely to be ENERGY STAR than those specified by builders. However, none of the differences are statistically significant at the 90% confidence level, due to the small sample sizes. Homes where the homeowners said they specified energy-efficient or ENERGY STAR appliances have similar proportions of ENERGY STAR refrigerators and dishwashers to all homes where appliances are specified by homeowners, but more ENERGY STAR clothes washers. Again, these proportions are based on very few responses.

**Table 12-10: ENERGY STAR Appliances and How Specified**

| Appliances | Specified by Builder | Specified by Homeowner | Homeowner Specified Energy-Efficient | Homeowner Specified ENERGY STAR |
|---|---|---|---|---|
| Primary Refrigerators | n=14 | n=53 | n=23 | n=16 |
| ENERGY STAR | 9 | 38(72%) | 17(74%) | 12(75%) |
| Not ENERGY STAR | 5 | 15 | 6 | 4 |
| Dishwashers | n=12 | n=50 | n=22 | n=15 |
| ENERGY STAR | 10 | 46(92%) | 21(95%) | 13(87%) |
| Not ENERGY STAR | 2 | 4 | 1 | 2 |
| Clothes Washers | n=14 | n=48 | n=21 | n=14 |
| ENERGY STAR | 9 | 33(69%) | 16(76%) | 11(79%) |
| Not ENERGY STAR | 5 | 15 | 5 | 3 |

# Appendix A Comparison to 2006 IECC Prescriptive Insulation Levels by Site

### Table A-1: Comparison to 2006 IECC Prescriptive Insulation Levels by Site

| Site | Custom/ Spec Home | Wood Framed Wall R-19 | Foundation Wall R-10/R-13 (cont/cavity) | Duct Insulation R-8 | Ceiling Insulation R-38 | Floor Insulation over Unconditioned Space R-30 or Cavity Filled | Applicable Prescriptive Requirements Met |
|---|---|---|---|---|---|---|---|
| **23** | **Spec** | Meet | Exceed | Meet | Lower | Meet | 4 out of 5 |
| **24** | **Spec** | Meet | Exceed | Lower | Meet | Meet | 4 out of 5 |
| **1** | **Custom** | Meet | Exceed | Meet | Lower | Lower | 3 out of 5 |
| **6** | **Custom** | Meet | Exceed | Lower | Lower | Meet | 3 out of 5 |
| **11** | **Custom** | Meet | Exceed | Lower | Lower | Meet | 3 out of 5 |
| **26** | **Spec** | Meet | Exceed | Lower | Meet | Lower | 3 out of 5 |
| **27** | **Spec** | Meet | Exceed | Lower | Exceed | Lower | 3 out of 5 |
| **28** | **Spec** | Meet | Exceed | Lower | Lower | Meet | 3 out of 5 |
| **36** | **Spec** | Meet | Exceed | Lower | Lower | Meet | 3 out of 5 |
| **39** | **Spec** | Meet | Exceed | Lower | Lower | Lower | 2 out of 5 |
| **42** | **Spec** | Meet | Exceed | Lower | Lower | Lower | 2 out of 5 |
| **10** | **Custom** | Meet | Exceed | Meet | Lower | n/a | 3 out of 4 |
| **34** | **Spec** | Meet | Exceed | n/a | Meet | Lower | 3 out of 4 |
| **43** | **Spec** | Meet | Exceed | Lower | Lower | Unknown | 2 out of 4 |
| **51** | **Spec** | Meet | Exceed | n/a | Lower | Lower | 2 out of 4 |
| **37** | **Spec** | Meet | Lower | Lower | Meet | Lower | 2 out of 5 |
| **21** | **Custom** | Lower | Lower | Lower | Meet | Lower | 1 out of 5 |
| **15** | **Custom** | Exceed | Lower | Meet | Lower | n/a | 2 out of 4 |
| **2** | **Custom** | Meet | n/a | Exceed | Exceed | Lower | 3 out of 4 |
| **3** | **Custom** | Meet | n/a | Lower | Exceed | Meet | 3 out of 4 |
| **4** | **Custom** | Meet | n/a | Meet | Lower | Meet | 3 out of 4 |
| **5** | **Custom** | Meet | n/a | Lower | Exceed | Meet | 3 out of 4 |
| **7** | **Custom** | Meet | n/a | Meet | Lower | Meet | 3 out of 4 |
| **25** | **Spec** | Meet | n/a | Exceed | Meet | Lower | 3 out of 4 |
| **29** | **Spec** | Meet | n/a | Lower | Meet | Meet | 3 out of 4 |
| **30** | **Spec** | Meet | n/a | Exceed | Lower | Meet | 3 out of 4 |
| **31** | **Spec** | Meet | n/a | Lower | Exceed | Meet | 3 out of 4 |
| **32** | **Spec** | Meet | n/a | Lower | Exceed | Meet | 3 out of 4 |
| **35** | **Spec** | Meet | n/a | Meet | Lower | Meet | 3 out of 4 |
| **12** | **Custom** | Meet | n/a | Exceed | Lower | Lower | 2 out of 4 |
| **13** | **Custom** | Meet | n/a | Lower | Lower | Meet | 2 out of 4 |
| **14** | **Custom** | Meet | n/a | Lower | Lower | Meet | 2 out of 4 |
| **38** | **Spec** | Meet | n/a | Meet | Lower | Lower | 2 out of 4 |
| **40** | **Spec** | Meet | n/a | Lower | Exceed | Lower | 2 out of 4 |
| **41** | **Spec** | Meet | n/a | Lower | Meet | Lower | 2 out of 4 |
| **44** | **Spec** | Meet | n/a | Lower | Meet | Lower | 2 out of 4 |
| **45** | **Spec** | Meet | n/a | Lower | Lower | Meet | 2 out of 4 |
| **46** | **Spec** | Meet | n/a | Lower | Lower | Meet | 2 out of 4 |
| **47** | **Spec** | Meet | n/a | Lower | Lower | Meet | 2 out of 4 |

| Site | Custom/ Spec Home | Wood Framed Wall R-19 | Foundation Wall R-10/R-13 (cont/cavity) | Duct Insulation R-8 | Ceiling Insulation R-38 | Floor Insulation over Unconditioned Space R-30 or Cavity Filled | Applicable Prescriptive Requirements Met |
|---|---|---|---|---|---|---|---|
| **48** | **Spec** | Meet | n/a | Lower | Lower | Meet | 2 out of 4 |
| **49** | **Spec** | Meet | n/a | Lower | Lower | Meet | 2 out of 4 |
| **50** | **Spec** | Exceed | n/a | Lower | Lower | Meet | 2 out of 4 |
| **52** | **Spec** | Meet | n/a | Meet | Lower | Lower | 2 out of 4 |
| **16** | **Custom** | Meet | n/a | Lower | Lower | Lower | 1 out of 4 |
| **17** | **Custom** | Meet | n/a | Lower | Lower | Lower | 1 out of 4 |
| **19** | **Custom** | **Meet** | **n/a** | **Lower** | **Lower** | **Lower** | **1 out of 4** |
| **20** | **Custom** | Meet | n/a | Lower | Lower | Lower | 1 out of 4 |
| **53** | **Spec** | Exceed | n/a | Lower | Lower | Lower | 1 out of 4 |
| **54** | **Spec** | Meet | n/a | Lower | Lower | Lower | 1 out of 4 |
| **55** | **Spec** | Meet | n/a | Lower | Lower | Lower | 1 out of 4 |
| **56** | **Spec** | Meet | n/a | Lower | Lower | Lower | 1 out of 4 |
| **57** | **Spec** | Meet | n/a | Lower | Lower | Lower | 1 out of 4 |
| **58** | **Spec** | Meet | n/a | Lower | Lower | Lower | 1 out of 4 |
| **59** | **Spec** | Meet | n/a | Lower | Lower | Lower | 1 out of 4 |
| **60** | **Spec** | Meet | n/a | Lower | Lower | Lower | 1 out of 4 |
| **61** | **Spec** | Meet | n/a | Lower | Lower | Lower | 1 out of 4 |
| **62** | **Spec** | Meet | n/a | Lower | Lower | Lower | 1 out of 4 |
| **63** | **Spec** | Exceed | n/a | Lower | Lower | Lower | 1 out of 4 |
| **64** | **Spec** | Meet | n/a | Lower | Lower | Lower | 1 out of 4 |
| **66** | **Spec** | Meet | n/a | Lower | Lower | Lower | 1 out of 4 |
| **22** | **Custom** | Lower | n/a | Lower | Lower | Lower | 0 out of 4 |
| **8** | **Custom** | Meet | n/a | n/a | Meet | Meet | 3 out of 3 |
| **9** | **Custom** | Meet | n/a | n/a | Meet | Meet | 3 out of 3 |
| **33** | **Spec** | Meet | n/a | n/a | Exceed | Meet | 3 out of 3 |
| **18** | **Custom** | Lower | n/a | n/a | Meet | Lower | 1 out of 3 |
| **65** | **Spec** | Meet | n/a | Lower | No Info | Lower | 1 out of 3 |
| **67** | **Spec** | Lower | n/a | Meet | Lower | n/a | 1 out of 3 |
| **69** | **Spec** | Lower | n/a | Lower | Lower | Unknown | 0 out of 3 |
| **68** | **Spec** | Meet | n/a | n/a | Lower | Unknown | 1 out of 2 |

# Appendix B Comparison of Custom and Spec Homes

**Table B-1: Comparison of Custom and Spec Homes**

| Building Component or Measure | All Homes (n=69)* | Custom Homes (n=22)* | Spec Homes (n=47)* |
|---|---|---|---|
| Average Square Feet of Conditioned Floor Area | 2,758 | 3,036 | 2,628 |
| **Conditioned/Ambient Wall Insulation Levels** | | | |
| Average Conditioned/Ambient Exterior Wall R-value | 19.0 | 18.7 | 19.1 |
| Percent of Homes Meeting 2006 IECC | 93% | 86% | 96% |
| **Conditioned/Basement Floor Insulation Levels** | | | |
| Average R-value of Floor Insulation over Unconditioned Basements | 20.5 | 22.6 | 19.5 |
| Percent of Homes Meeting 2006 IECC | 40% | 50% | 36% |
| **Flat Ceiling Insulation Levels** | | | |
| Average Flat Ceiling Insulation R-value | 34 | 34 | 33 |
| Percent of Homes Meeting 2006 IECC | 30% | 32% | 28% |
| **Cathedral Ceiling Insulation Levels** | | | |
| Average Cathedral Ceiling Insulation R-value | 32 | 32 | 32 |
| Percent of Homes Meeting 2006 IECC | 75% | 83% | 71% |
| **All Ceiling Insulation Levels** | | | |
| Percent of Homes Meeting 2006 IECC | 29% | 32% | 28% |
| **Foundation Wall Insulation Levels** | | | |
| Average Foundation Wall Insulation R-value | 17.3 | 14.0 | 19.0 |
| Percent of Homes Meeting 2006 IECC | 83% | 67% | 92% |
| **Windows** | | | |
| Average Percent Glazing (% of Wall Area) | 16% | 16% | 15% |
| Average Percent of Total Glazing on South Walls (S, SE, SW) | 37% | 37% | 37% |
| **Heating Systems** | | | |
| Percent ENERGY STAR heating systems | 85% | 90% | 82% |
| Average Heating System Sizing Ratio | 1.66 | 2.01 | 1.49 |
| **Central Air Conditioning** | | | |
| Average Central Air Conditioning SEER | 13.4 | **13.8**** | **13.2**** |
| Average Cooling System Sizing Ratio | 1.99 | 2.01 | 1.99 |
| **Conventional Fossil-Fuel FiredWater Heaters** | | | |
| Average Energy Factor | 0.63 | 0.62 | 0.63 |
| **Ducts** | | | |
| Average R-value Duct Insulation--All Ducts in Unconditioned Space | 7.1 | **7.6**** | **7.0**** |
| Average Duct Leakage CFM25 per 100 Sq. Ft. Conditioned Space | 17.7 | 17.1 | 18.0 |
| **Air Infiltration** | | | |
| Average Air Changes per Hour at 50 Pascals (ACH50) | 5.8 | 6.1 | 5.7 |
| Average CFM50 Leakage | 2,179 | 2,430 | 2,061 |
| **Lighting** | | | |
| Average Percent of Fixtures Containing Energy-Efficient Bulbs | 10% | 7% | 12% |
| Average Number Of Fixtures Containing Energy-Efficient Bulbs | 4.4 | 4.9 | 4.2 |
| **Appliances** | | | |
| Percent Primary Refrigerators ENERGY STAR | 71% | 59% | 77% |
| Percent Dishwashers ENERGY STAR | 90% | **100%**** | **85%**** |
| Percent Clothes Washers ENERGY STAR | 67% | 72% | 65% |

*The numbers of homes are the total number of homes in the studies. Not all homes have all features; therefore, the numbers of homes with a specific feature vary.

** Significantly different at the 90% confidence level

# Appendix C 2006 IECC Prescriptive Requirements

| Climate Zone | Fenestration U-value | Skylight U-value (2) | Glazed Fenestration SHGC | Ceiling R-value | Wood Frame Wall R-value | Mass Wall R-value | Floor R-value | Basement Wall R-value (3) | Slab R-value, Depth (4) | Crawlspace Wall R-value (3) |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 1.20 | 0.75 | 0.40 | R-30 | R-13 | R-3 | R-13 | R-0 | R-0 | R-0 |
| **2** | 0.75 | 0.75 | 0.40 | R-30 | R-13 | R-4 | R-13 | R-0 | R-0 | R-0 |
| **3** | 0.65 | 0.65 | 0.40 (5) | R-30 | R-13 | R-5 | R-19 | R-0 | R-0 | R-5/13 |
| **4 except marine** | 0.40 | 0.60 | NR | R-38 | R-13 | R-5 | R-19 | R-10/13 | R-10, 2 ft | R-10/13 |
| **5 and marine 4** | 0.35 | 0.60 | NR | R-38 | R-19 or 13+5 (7) | R-13 | R-30 (6) | R-10/13 | R-10, 2 ft | R-10/13 |
| **6** | 0.35 | 0.60 | NR | R-49 | R-19 or 13+5 (7) | R-15 | R-30 (6) | R-10/13 | R-10, 4 ft | R-10/13 |
| **7 and 8** | 0.35 | 0.60 | NR | R-49 | R-21 | R-19 | R-30 (6) | R-10/13 | R-10, 4 ft | R-10/13 |

IECC 2006 Table 402.1.1 Insulation and Fenestration Requirements by Component (1)

1. *R-values are minimums. U-values and SHGC are maximums. R-19 shall be permitted to be compressed into a 2x6 cavity.*
2. *The fenestration U-value column excludes skylights. The SHGC column applies to all glazed fenestration.*
3. *The first R-value applies to continuous insulation, the second to framing cavity insulation; either insulation meets the requirement.*
4. *R-5 shall be added to the required slab edge R-values for heated slabs.*
5. *There are no SHGC requirements in the Marine zone.*

6. *Or insulation sufficient to fill the framing cavity, R-19 minimum.*
7. *"13+5" means R-13 cavity insulation plus R-5 insulated sheathing. If structural sheathing covers 25% or less of the exterior, insulating sheathing is not required where structural sheathing is used. If structural sheathing covers more than 25% of exterior, structural sheathing shall be supplemented with insulated sheathing of at least R-2.*

Source: **http://www.greenbuildingadvisor.com/community/forum/building-code-questions/17176/definition-floor**

# Appendix D 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.[57]

**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.

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

Figure D-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.[58]

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

Figure D-2 shows a Grade II install of unfaced fiberglass batts in a conditioned basement.[59] 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 D-2: Grade II Fiberglass Batts—Basement Walls**

[58] 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.

[59] The basement in this case was considered conditioned volume, not conditioned floor area.

Figure D-3**Error! Reference source not found.** 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 D-3: Grade III Fiberglass Batts—Attic Kneewalls**

Figure D-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 D-4: Grade II Fiberglass Batts—Frame Floor**

Figure D-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 D-5: Grade III Fiberglass Batts—Frame Floor**

Figure D-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 D-6: Grade I Blown Fiberglass—Attic**

# Appendix E Building Practices—Examples from the Site Visits

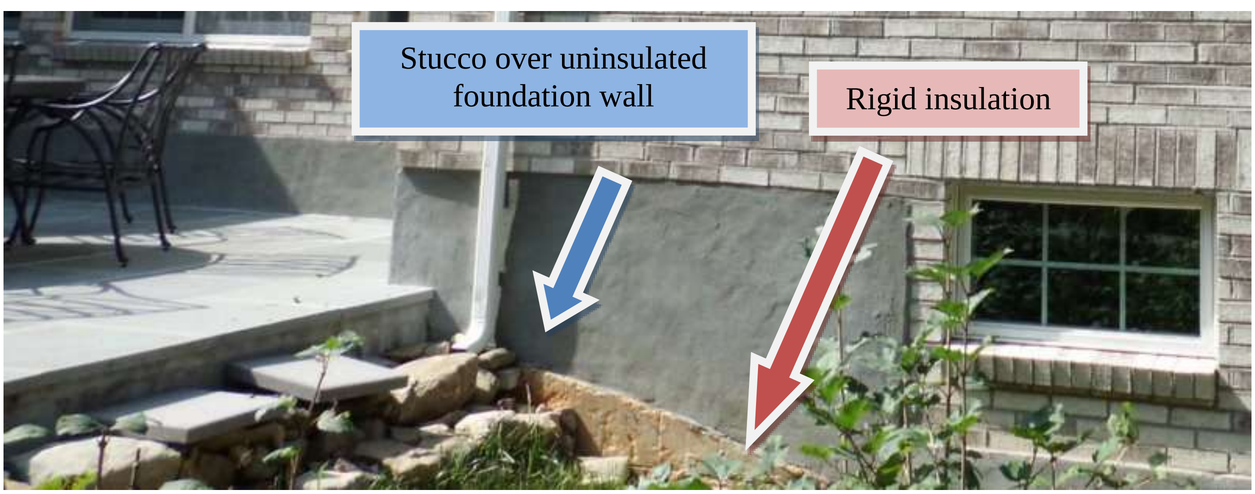
During their visits to new homes, auditors photographed examples of good building practices that contributed to a home's energy efficiency and poor building practices where the builder missed opportunities to improve the home's energy efficiency. Below are examples of the practices that auditors saw 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.)[60]

Figure E-1 demonstrates where a builder attempted to bring the walkout basement into the thermal envelope by insulating the foundation walls with rigid foam. However, there was no insulation on the above grade portion of the concrete wall, where the foam would have provided substantial benefit (the insulation was only visible in the area shown in the below photo). The builder should have installed the rigid foam insulation on the entire foundation wall, including the above grade portion, and then painted it if aesthetics were a concern – in fact, the builder applied stucco over the above grade portion of the foundation wall anyway. Not continuing the insulation all the way up the foundation wall was a lost opportunity for energy savings, and for making the basement more comfortable.

**Figure E-1: Foundation Wall Rigid Insulation**




[60] 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 E-2 shows a walkout basement viewed from the inside. The above grade stud walls in this example were well insulated with fiberglass batts and covered with a silver, reflective air barrier. 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.

**Figure E-2: Insulated Walkout Basement Walls**

Figure E-3 demonstrates an energy inefficient walkout basement configuration. The above grade stud wall on the walkout portion of the basement – visible behind the boiler in the photo – was completely uninsulated. Only vinyl siding and a sheet of plywood separated the basement from ambient conditions. In addition, there was no frame floor insulation above this uninsulated basement, and the hydronic heat lines were uninsulated – a fairly common sight in the homes auditors visited.

**Figure E-3: Uninsulated Above Grade Basement Walls**

## *Slab Floors*

Slab floors 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 property.

## *Frame Floors*

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

Figure E-4 shows poorly installed frame floor insulation. This installation of R-30 fiberglass batts had significant gaps, sagging, and compression, particularly in bays with ductwork or plumbing lines. Some of the batts were installed upside down, and some bays were entirely lacking insulation.

**Figure E-4: Poorly Installed Frame Floor Insulation**

Figure E-5 shows another particularly poor frame floor insulation installation. R-19 fiberglass batts were sloppily installed at the bottom of a floor truss system, such that their Kraft facing was nearly one foot below the subfloor, there were huge areas lacking insulation, and the insulation itself was heavily compressed. This insulation was providing very little, if any, benefit.

**Figure E-5: Poorly Installed Frame Floor Insulation**

Figure E-6 shows frame floor insulation that was well installed and in substantial contact with the subfloor. However, there were significant gaps in the insulation to accommodate the installation of hot water and HVAC lines. HVAC and plumbing contractors not working in conjunction with insulation contractors often created such conflicts. Note that in this photo, the hot water lines in the basement were uninsulated; this was a common oversight among builders, for both domestic hot water and hydronic heating pipes.

**Figure E-6: Gaps in Frame Floor Insulation and Uninsulated DHW Lines**

## *Rim/Band Joists & Sealing Penetrations to the Outside*

Rim joists were commonly insulated by the same fiberglass batts that insulated 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.

Figure E-7, in contrast, shows a home with well installed, closed cell foam insulating the rim joist in an unconditioned basement.[61] Such foam fully sealed gaps around utility penetrations to the outdoors, minimizing air leakage in the basement. Homes with this type of spray foam in the rim joists, rather than the more common fiberglass batts, 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 E-7: Rim Joist Insulated with Spray Foam**

[61] This home did not have frame floor insulation over the basement because the basement was insulated and within the thermal boundary.

## *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 E- 8, in contrast, shows a home with closed cell spray foam in all of the exterior walls, including the basement walls. The foundation walls in the basement, visible in this photo, were framed with a 2x4 wall two inches away from the concrete wall, so that 3.5 inches of foam could be sprayed between the studs, and an additional two inches of foam could fill the space between the concrete foundation wall and the stud wall, creating an excellent air and thermal barrier.

**Figure E- 8: Walls with Closed Cell Spray Foam Insulation**

Figure E-9, in contrast, shows a fairly sloppy knee wall insulation installation. The fiberglass batts have no air barrier on the attic side, they are compressed rather than cut to fit around wiring, and some of them are falling out of their cavities. Such sloppiness was common in areas that were not readily accessible by the homeowner (knee walls, attics, etc.).

**Figure E-9: Poorly Installed Fiberglass Wall Insulation**

## *Ceiling and Attic Insulation*

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

Figure E-10 shows a poor attic insulation installation. The R-30 fiberglass batts were sloppily installed, particularly where they interfered with HVAC equipment and ducts in the attic. This is another example of the problems that arise when insulation and HVAC contractors do not work collaboratively. In addition, the home could have benefited from the use of readily available R-38 batts rather than the R-30 batts used by the builder.

**Figure E-10: Poorly Installed Fiberglass Batt Attic Insulation**

Figure E-11 shows well installed blown-in fiberglass insulation in an attic. The distribution is relatively even and there are wind baffles. Ideally there would not have been ductwork in the vented, unconditioned attic, but at least the ductwork was partially buried under the fiberglass insulation.

Interestingly, this builder also added a raised wood platform that allows the homeowner to store things in the attic without crushing the insulation. Attics with blown-in insulation are usually unavailable for storage.

**Figure E-11: Blown-in Fiberglass Attic Insulation with Storage Platform**

## *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 E-12 shows a basement window where small pieces of fiberglass insulation were stuffed between the window frame and the rough opening of the window, creating a poor air barrier. Windows and doors in basements and joints between concrete and stud framing would have often benefited from the use of spray foam as an air sealing measure. While this house at least had fiberglass stuck in these gaps, many homes had nothing to seal these gaps, allowing significant air leakage into basements.[62]

**Figure E-12: Fiberglass as Ineffective Air Sealing**

[62] Auditors could often find these leakage points quickly by looking for spider webs, as spiders often spin their webs in front of air currents.

### 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.

Figure E-13 shows an attic space with foam insulation sprayed between the roof rafters, bringing the attic heating system and ducts into the conditioned space. In addition, the builder installed a radiant barrier over the roof rafters. There were gaps in the radiant barrier, thereby decreasing its functionality, but the builder was attempting to improve upon the common practice of installing a heating system in an uninsulated, vented attic.

**Figure E-13: HVAC System in Conditioned Attic**

In contrast, Figure E-14 shows a vented attic space separated from conditioned space by an insulated knee wall on the right. Ductwork was run through this space, and all duct leakage was completely lost to the outside. The HVAC contractor also completely bent one of the flexible ducts in half to avoid an obstruction, constricting its airflow and compressing its insulation. Flexible ducts were often twisted and crushed in this manner.

Also, the knee wall insulation would have benefited from an air barrier on the attic side, as wind could blow directly through the soffit vents, wind-washing the exposed fiberglass batts on the right. The builder had also used blown-in fiberglass above the ceiling of the room below this attic space, which performed better than the sloppy fiberglass batts commonly seen in cramped spaces behind knee walls.

**Figure E-14: Kinked Ducts Exposed to Wind-Washing Behind Knee Wall**

**Error! Reference source not found.**, cited later as an example of an oversized mechanical system, shows a mechanical system in an unconditioned basement with a completely uninsulated return trunk, and an uninsulated supply plenum. The ductwork is also not sealed with mastic or metal tape. Builders rarely left large sections of supply ducts uninsulated in unconditioned basements, and typically insulated the return ducts as well.

### *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 E-15 shows one of the few examples of a home with extra insulation wrap around a water heater. This simple measure was very uncommon in new homes. Note, however, that the hot water lines were not insulated.

**Figure E-15: Insulated Indirect Water Heater**

Looking back at **Error! Reference source not found.**, one can also see in this photo an example of a hydronic heating system with no insulation on the hot water lines. This is particularly problematic in a completely uninsulated basement, where the water lines are exposed to fairly cold temperatures in the winter. This house lacked insulation in its basement walls, frame floor, and on the hot water lines in the cold basement – multiple gross oversights.

Figure E-16 shows an HVAC system where significant portions of the supply and return ducts in an unconditioned basement were uninsulated. In addition, this system had a “pressure relief diverter” installed. This opening in the supply plenum bleeds off conditioned air into the basement to control unwanted air pressure, noise, or uneven air delivery, likely caused by an oversized HVAC system. Several homes had these configurations; some, like in this photo, allowed air to blow out into the basement, largely wasted, while others were connected directly to the return plenum, returning the air immediately to the air handler.

**Figure E-16: Pressure Relief Diverter & Uninsulated Supply and Return Ducts**

Figure E-17 also shows improperly installed and designed ductwork. The contractor failed to properly secure the supply ductwork in this walkout basement, allowing multiple lengths of flexible duct all over the basement to hang down from the basement ceiling. The homeowner reported to the auditors that these supply ducts were added in the basement to serve as a pressure release mechanism for the ductwork in the rest of the house. This indicates that the HVAC contractors had not properly designed or sized the HVAC system, and had certainly failed to install the ductwork properly.

**Figure E-17: Hanging Flexible Ducts Serving as Pressure Relief**

Builders also often installed lower efficiency, non-condensing furnaces in attics, perhaps due to the risk of condensate freezing in unconditioned attics.[63] Bringing mechanical 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.

[63] 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.

# Appendix F HVAC Performance Testing

As part of the 2011 Connecticut Residential New Construction (RNC) Baseline study, 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. This appendix describes the in-field measurements, equipment, protocols and analytical procedures used to determine the actual operating characteristics of the systems. Central heat pumps were included in the sample, but only the cooling performance of these was considered. Although some of the RNC sample homes used window air conditioners, these units were not included in the CAC analysis.

*Field Measured Data:* The measurements required to properly assess the operating performance of the CACs included air side temperature and flow rates along with electric power draws of the condensing units and blower motors with controls. Although duct 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 include 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 pressure 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 include:

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

*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, auditors used relatively high precision thermometers and power meters and utilized a “True Flow Array” designed specifically for the purpose of measuring air flow through a CAC system.

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

- “True Flow Array” 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.

*Field Measurement Protocols:* Auditors were 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 accurately 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 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 as needed 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.

*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 fully in this report, 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 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.

*Results:* The overall results of this study are summarized in Table F-1Table ES 1, which shows the average values of the 41 sites that yielded reasonable results:

**Table F-1: Rated vs. Measured Operating Performance of CACs**

| CAC Testing Results (n=41) | Rated | Operating | Difference | Relative Error |
|---|---|---|---|---|
| **Capacity Btuh** | 37,024 | 31,329 | -15.4% | 8.4% |
| **SEER** | 13.2 | 12.0 | -8.9% | 6.5% |

The average rated capacity and efficiency is 37,024 Btuh (3.09 tons) and 13.2 SEER, as shown. The average operating capacity and efficiency is somewhat lower, at 31,329 Btuh (2.61 tons) and 12.0 SEER.

The maximum difference between rated and operating capacity is 3.9% and the minimum is -52.0%. At the same time, the maximum difference between rated and operating efficiency is 23.3% and the minimum is -52.1%. These ranges could indicate a wide range of actual operating conditions, but are more likely due to measurement errors.

Statistical Z tests confirm that the average values in the table are statistically significant, indicating that these values are valid indicators of the field performance condition overall. However, the individual site performance comparisons may not be valid due to inherent measurement errors.

Procedures required to obtain precise measurements of field operating conditions for any individual site would require more precise instrumentation and more on-site time. 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.

# Appendix G 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 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
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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 |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
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Notes:

### Frame Floor

*Note where insulation was verified.*

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

Notes:

### Rim/ Band Joists

*Note where insulation was verified.*

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

Notes:

### Exterior Walls

*Note where insulation was verified.*

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

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

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

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

| Sky Lights | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Type of Glass | SqFt | Frame | Location | U-value | SHGC | T Break | Orient | Angle |
| | | | | | | | | |
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| | | | | | | | | |
| 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 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
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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 w ater heater w rap:

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 |
| | | | | | | | |
| | | | | | | | |
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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 | No. of Incan. Fixtures | No of Fluor. Tube Fixtures | No of LED Fixtures | # of Ceiling Fans by Room |
|---|---|---|---|---|---|
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## 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 | | | | | | | |

## 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: |
|---|---|---|---|
| | | | |
| | | | |

# Appendix H On-site Homeowner Survey Instrument

## CONNECTICUT ON-SITE SURVEY QUESTIONS

**SITE ID:__________**

**OWNER NAME:____________________________________________________________**

**HOME ADDRESS: ____________________________________________________________**

1. Name of Builder or Development: ____________________________________

2. Have you ever participated in an energy efficiency program through your utility? Yes___ No___ ***(IF NO, skip to question 4)***

   2.1. **IF YES:** What programs have you participated in?

   2.1.1. Home Energy Solutions (a home assessment and direct install program): Yes___ No___

   2.1.2. Appliance Rebate programs: Yes___ No___

   2.1.3. Home Energy Reports (get reports in mail comparing your usage to nearby households): Yes___ No___

   2.1.4. Other program(s): ________________________________________________________________

3. I am going to read a list of reasons why some people participate in energy conservation programs. On a scale of 0 to 10, with 0 meaning not at all a reason for you, and 10 meaning a very important reason for why you might decide to participate in an efficiency program, please rate each reason as I read it:

| | Not at All | | | | | → | | | | | Very Important | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. It's good for the environment | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | NC |
| B. It saves money on my electric bill | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | NC |
| C. It saves money on my fuel bill | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | NC |
| D. My neighbors/friends recommend it | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | NC |
| E. It helps to keep everyone's electric rates down | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | NC |
| F. It will reduce the need for new power plants | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | NC |
| G. It makes my home more comfortable | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | NC |
| H. It prolongs the life of my home | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | NC |
| I. It prolongs the life of my HVAC equipment | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | NC |

4. Which of the following best describes how you purchased your home? **(Check one)**
   4.1. Purchased land and worked with an architect and/or builder to design and build the home: ______
   4.2. Had a house plan and a lot and hired a contractor/builder to build the home: ____
   4.3. Purchased a lot from a builder, selected one of several house plans offered by builder: ____
      4.3.1. Were you able to select from various available upgrade options? Yes___ No___
   4.4. Purchased a home that was under construction: ___
      4.4.1. Were you able to select from various available upgrade options? Yes___ No___
   4.5. Purchased a finished home: ___
   4.6. I am the owner and builder. ___
   4.7. Other→ Please describe: ________________________________________

5. Did your builder or real estate agent ever talk to you about energy efficiency or the benefits of energy-efficient windows, heating and cooling equipment, insulation, etc.?
   5.1. Yes ____
   5.2. No ____
   5.3. Do not remember ____

   Comments:
   ________________________________________________________________________________
   ________________________________________________________________________________
   ________________________________________________________________________________
   ________________________________________________________________________________

6. Did you ask your builder or the real estate agent marketing your home about the energy efficiency of this home?
   6.1. Asked about energy efficiency: ____
   6.2. Did not ask about energy efficiency:____
   6.3. Do not remember:____

   Comments:
   ________________________________________________________________________________
   ________________________________________________________________________________
   ________________________________________________________________________________
   ________________________________________________________________________________

7. How important, if at all, 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 energy efficient do you think your home is compared to other new homes?

   8.1. Much more energy efficient: ____
   8.2. Somewhat more energy efficient: ____
   8.3. About as energy efficient as most other new homes: ____
   8.4. Somewhat less energy efficient: ____
   8.5. Much less energy efficient: ____
   8.6. Do not know: ____

      8.6.1. Why do you say that?
      ______________________________________________________________
      ______________________________________________________________
      ______________________________________________________________
      ______________________________________________________________

9. If you built a custom home or purchased your home before it was completed and had the opportunity to choose various options for your home, please let me know, as far as you know, who made the decision for each of the following energy efficiency-related components in your home?

   **9.1. Windows:**

      9.1.1. I Specified:____

         9.1.1.1. Do you remember what you specified? (*Check all that apply.*)

            9.1.1.1.1. The style (double hung, casement, awning, slider, frame material or color, panes dividers, etc.): ____
            9.1.1.1.2. Number of panes of glass (single-, double- or triple-pane): ____
            9.1.1.1.3. Energy efficiency (U-value):____
            9.1.1.1.4. ENERGY STAR windows:____

      9.1.2. Builder chose: ____
      9.1.3. Selected from options offered by the builder:____
      9.1.4. Do not remember or do not know: ____

**9.2. Heating system:**

9.2.1. I Specified:____

9.2.1.1. Do you remember what you specified? (*Check all that apply.*)

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

9.2.2. Builder chose: ____
9.2.3. Selected from options offered by the builder:____
9.2.4. Do not remember or do not know: ____

**9.3. Central Air Conditioning:**

9.3.1. I Specified:____

9.3.1.1. Do you remember what you specified? (*Check all that apply.*)

9.3.1.1.1. Whether or not to install central air conditioning:___
9.3.1.1.2. Type of system (standard central A/C system, air source heat pump, ductless mini-split, combined heating and cooling system): ____
9.3.1.1.3. Energy efficient system:____
9.3.1.1.4. ENERGY STAR-labeled system:____

9.3.2. Builder chose: ____
9.3.3. Selected from options offered by the builder:____
9.3.4. Do not remember or do not know: ____

**9.4. Water heating:**

9.4.1. I Specified:____

9.4.1.1. Do you remember what you specified? (*Check all that apply.*)

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

9.4.2. Builder chose: ____
9.4.3. Selected from options offered by the builder:____
9.4.4. Do not remember or do not know: ____

**9.5. Kitchen Appliances:**

9.5.1. I Specified:____

9.5.1.1. Do you remember what you specified? (*Check all that apply.*)

9.5.1.1.1. Gas or electric:___
9.5.1.1.2. Brand/manufacturer:_____
9.5.1.1.3. Color/style:___
9.5.1.1.4. Energy efficient appliances:____
9.5.1.1.5. ENERGY STAR-labeled appliances:____

9.5.2. Builder chose: ____
9.5.3. Selected from options offered by the builder:____
9.5.4. Do not remember or do not know: ____

9.6. **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.)

9.6.1. I Specified:___
9.6.2. Builder chose: ____
9.6.3. Selected from options offered by the builder:____
9.6.4. Do not remember or do not know: ____

**9.7. Type and/or level of insulation:**

9.7.1. I Specified:____

9.7.1.1. Do you remember what you specified? (*Check all that apply.*)

9.7.1.1.1. Type of insulation *(fiberglass batts, blown-in cellulose, spray foam, rigid foam, etc.)*:____
9.7.1.1.2. Level of insulation (R-value):____

9.7.2. Builder chose: ____
9.7.3. Selected from options offered by the builder:____
9.7.4. Do not remember or do not know: ____

**9.8. Lighting Fixtures:**

9.8.1. I Specified:____

9.8.1.1. I could choose any fixtures from any stores:____
9.8.1.2. I was given a budget allowance to use at a specific store or catalog:____
9.8.1.3. I wanted energy –efficient lighting fixtures:___
9.8.1.4. I wanted ENERGY STAR lighting fixtures:

9.8.2. Builder chose: ____
9.8.3. Selected from options offered by the builder:____
9.8.4. Do not remember or do not know: ____

10. What other options did you specify or select?
    10.1. _______________
    10.2. _______________
    10.3. _______________
    10.4. _______________
    10.5. _______________

**THANK YOU**