2015-16 Massachusetts Single-Family Code Compliance/Baseline Study: Volume 3-Final Report

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Volume Number 3

BASELINE FINDINGS

SUBMITTED TO:
The Electric and Gas Program Administrators of Massachusetts

SUBMITTED BY:
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ES Executive Summary

One of the primary goals of the 2015 Single-Family Compliance/Baseline study is to provide the information needed to update the User Defined Reference Home (UDRH) for the low-rise component (residential buildings three stories or lower) of the Residential New Construction (RNC) program. This report volume was designed with a focus on providing this information. Specifically, this report volume provides information on the following items:

- Preliminary UDRH Inputs
- High-level findings for the efficiency of various building components that were inspected as part of the on-site inspections
- Comparison of 2015 baseline study homes to 2015 RNC program homes
- Comparison to previous baseline studies

To provide the most useful information for the focus areas listed above, the Team has limited the presentation of data from the on-site inspections to represent only homes built at the beginning of the 2012 IECC cycle and homes built under the stretch code, which is currently based on 2009 IECC, for this report volume. There are a couple of reasons for this:

- In order to update the UDRH, the Team, Program administrators (PAs) and Energy Efficiency Advisory Council (EEAC) Consultants have agreed that using the results of the most recently built baseline study homes (i.e., 2012 IECC and stretch code homes) is the most appropriate approach.
- The 2015 MA RNC program primarily consisted of homes built at the beginning of the 2012 IECC cycle and homes built under the stretch code. Comparing non-program homes to program homes built in the same code cycles results in the most up-to-date and realistic representation of what is currently taking place in the market.
    - The working group discussed including program homes in the baseline sample. A concern was that not including program participants would have an upward bias on program savings. However, this concern was offset by a previous market effects and net-to-gross study[1] that showed significant spillover from the program to non-participating homes. Therefore, PAs and EEAC consultants agreed it was appropriate to exclude program homes from the 2015 baseline sample.

The baseline study inspection results for homes built at the end of the 2009 IECC cycle and for all the inspected homes are included in Volume 2: Data Analysis Findings.

[1] http://ma-eeac.org/wordpress/wp-content/uploads/Residential-New-Construction-Net-Impacts-Report-1-27-14.pdf

PRELIMINARY UDRH INPUTS

Section 2 presents the preliminary UDRH inputs that were used to facilitate a discussion around updating the current RNC programs' UDRH. Program Administrators, EEAC Consultants and representatives from the RNC implementation contractor (ICF International) reviewed these preliminary UDRH estimates and developed a final set of UDRH inputs that incorporates additional information based on experience administering the Program as well as information on specific measures that were found in either none or very few of the audited baseline homes. The final UDRH inputs are provided as an Addendum to this report.

The 2015 baseline preliminary estimated UDRH inputs suggest that the current UDRH assumptions may underestimate the efficiency for some current building practices or equipment. Examples of current UDRH inputs that may underestimate the efficiency of baseline homes include most shell measures (e.g., wall insulation and ceiling insulation), air leakage, duct leakage, and some mechanical equipment efficiencies. However, many of the UDRH inputs that exhibited improved efficiency are still below 2015 IECC code levels, exhibiting room for improvement, including building envelope insulation levels and air leakage.

COMPARISON TO PROGRAM HOMES

Section 9 presents a detailed comparison of the 2015 baseline study homes and the 2015 RNC program homes. The comparisons are based on unweighted REM/Rate data for 2015 program homes and inspected non-program baseline 2012 IECC and stretch code homes. Comparisons address walls, ceilings, floors, foundation walls, duct insulation, duct leakage, air infiltration and HERS scores.

For conditioned/ambient walls, ceilings, and floors, both R-values and U-values are addressed. U-values are the overall heat transfer coefficient for the entire wall, floor or ceiling assembly, not just the insulation. The lower the U-value is, the more energy efficient the assembly. U-values were calculated using REM/Rate software and 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.

In general, 2015 program homes are more efficient than the 2015 baseline study homes.

- Conditioned/ambient wall U-values, flat ceiling U-values, vaulted ceiling R-values and U-values, the R-values of foundation wall insulation in unconditioned basements, duct insulation R-values, duct leakage to the outside, air infiltration, and HERS scores are significantly better in program homes than in combined baseline 2012 IECC and stretch code homes.
- Although the differences are statistically insignificant, conditioned/ambient wall R-values, flat ceiling R-values, and conditioned/basement floor U-values are better in program homes than in combined baseline 2012 IECC and stretch code homes.

- Also statistically insignificant, in two cases combined baseline 2012 IECC and stretch code homes are more efficient than 2015 program homes—conditioned/basement floor R-values and foundation wall insulation R-values in conditioned basements. In both cases, the differences are small.

Comparison to Previous Baseline Studies

Section 10 presents a detailed comparison of the current unweighted baseline results, which combined 2012 IECC and stretch code homes, to Massachusetts baseline studies that were conducted in 1999, 2001, 2005, and 2011. The energy efficiency of single-family homes in Massachusetts has improved tremendously over time. Below are some highlights from the baseline study comparison analysis:

- **Building Envelope:** From the 1999 study to the 2015 study the average R-value of exterior walls increased from R-14.1 to R-20.8, the average R-value of flat ceiling insulation increased from R-30.5 to R-40.7, the average R-value of floor insulation increased from R-19.4 to R-30.7, and the average window U-value improved from 0.41 to 0.30.
- **Air Infiltration:** Air infiltration consistently dropped over the years from 6.7 ACH50 in the 2005 study to 3.6 ACH50 in the current study.
- **Duct Leakage:** Average duct leakage to the outside dropped sharply from 21.7 CFM25 per 100 square feet of conditioned floor area in the 2005 study to 12.4 in the 2011 study to 3.9 in the 2015 study.
- **Heating System Efficiency:** From the 2001 study to the 2015 study, the overall average AFUE of fossil fuel heating systems increased from 85.6 to 93.3. Over the same period, the percentage of homes with oil heating systems fell from 46% to two percent, the percentage of homes with propane heating systems grew from 4% to 32%, and the percentage of homes with natural gas heating systems climbed from 50% to 63%.
- **Water Heater Efficiency**: The overall average Energy Factor for water heaters has climbed from 0.59 in the 2001 study to 1.05 in the 2015 study; a large part of this increase reflects the increase in the penetration of natural gas and propane instantaneous water heaters from 1% to 27% and, for the first time, some homes in the current study had electric heat pump water heaters (13% of water heaters in the 2015 study).
- **Air Conditioning**: The percentage of homes with central air conditioning increased from study to study; from 56% in the 1999 study to 92% in the 2015 study, while the average SEER of central air conditioning systems increased from 10.2 SEER to 13.9 SEER.
- **Lighting:** There has been a dramatic increase in the proportion of energy-efficient lighting in homes from practically no energy-efficient bulbs in 2001 to 5% in 2005, 20% in 2011, and 48% of bulbs in 2015.

OVERALL STUDY FINDINGS, CONSIDERATIONS, AND RECOMMENDATIONS

Findings and recommendations from both the baseline and compliance reports are listed below:

Baseline Study Findings

- The 2015 baseline study results suggest that current UDRH inputs underestimate the efficiency for some current building practices and equipment.
- In general, building envelope characteristics, air infiltration, and duct leakage to the outside are significantly more energy efficient in 2015 program homes than in 2015 baseline study homes.
- Using HERS scores as an overall indication of a home's energy efficiency, average HERS scores show a clear difference in the overall energy efficiency of 2015 baseline homes compared to 2015 program homes and 2011 baseline study homes. The average HERS score of 55 for 2015 program homes is much lower (more energy efficient) than the unweighted average 68 HERS score or weighted average 67 HERS score for 2015 baseline homes; these differences are statistically significant. The average HERS scores of 2015 baseline homes (68 unweighted and 67 weighted) are significantly higher (better) than the average HERS scores of 2011 baseline homes (79 unweighted and 80 weighted).

Baseline Study Recommendations and Considerations

Recommendation: Studies suggest the manufacturer R-value ratings for bubble wrap duct insulation are overstated. **The program should inform HERS raters of this to ensure that all raters treat bubble wrap the same way when entering the information into REM/Rate.**

Recommendation: Going forward, the program will be incorporating water-saving UDRH inputs and will be calculating Domestic Hot Water (DHW) energy consumption more precisely. **Future baseline on-site inspections should include collecting data on the longest length of DHW piping (from water heater to fixture), level of DHW pipe insulation, hot water fixture flow rates, and presence of hot water drain recovery devices.** Installing these items in rated homes will provide savings to the program.

Consideration: If, going forward, the PAs consider including appliance efficiencies as UDRH inputs, then a working group should be set up to consider how to develop appropriate appliance efficiency inputs.

Consideration: Consider including builder and/or homeowner interviews/surveys in the next baseline study. This would add valuable qualitative information on building measure, mechanical equipment, lighting and appliance decisions.

Consideration: If results from a recent study of lighting in existing homes is available, it could be useful to compare lighting characteristics in newly constructed homes to lighting in existing homes.

Compliance Study Recommendation and Considerations

Recommendation: The PAs should focus CCSI training efforts on air and duct leakage requirements. These measures are mandatory requirements and show the largest opportunity for savings from compliance enhancement efforts. The Team anticipates that the savings potential for stretch code homes, as it pertains to these measures, will increase when the stretch code is updated to reflect the adoption of the 2015 IECC (effective as of January2017). Note that other shell measures show potential as well, but air and duct leakage appear to present the highest level of opportunity for the PAs. Lighting currently appears to present a large compliance enhancement opportunity, but the Team believes that lighting compliance is best addressed by relying on the upstream incentive programs in combination with the rapidly changing lighting market as opposed to CCSI training efforts. It is likely that homeowners in new homes will replace inefficient light bulbs with efficient LEDs at least at the same rate as homeowners in existing homes. Given that homeowners will likely be installing LED bulbs on their own, the Team does not believe a focused training effort on lighting through the CCSI is necessary.

Consideration #1: The PAs should consider addressing the proper documentation for stretch code home compliance in the CCSI trainings. The Team found that 46% of the non-program stretch code homes in the baseline study sample did not meet the stretch code HERS score requirements. Moreover, in a previous study, the Team found that only 51% of stretch code homes had documentation of a confirmed HERS rating on file at building departments.[2] These findings suggest that code officials may not be aware of the proper documentation required for stretch code homes or the HERS score requirements associated with the stretch code.

Consideration #2: The PAs should consider abandoning the PNNL compliance approach. As shown in Section 2.3**Error! Reference source not found.** of the Volume 4 compliance study, the MA-REC approach is more calibrated to overall building efficiency than the PNNL approach. The MA-REC approach also more accurately summarizes the potential savings associated with bringing homes up to the prescriptive code requirements of various energy codes. Moreover, PNNL informed the Team that they are no longer supporting the checklist methodology (they do not have a checklist for the 2015 IECC). The PNNL approach has value because it is informative to understand how builders are complying with the code and how market actors are complying with administrative and non-energy-related requirements; however, the Team believes this information can be assessed without completing PNNL code compliance checklists. Lastly, moving forward, the MA-REC approach will likely be cheaper to implement, assuming REM/Rate energy models are available to leverage for future compliance assessments.

Consideration #3: The PAs should consider conducting further research to develop a compliance methodology that accurately accounts for the trade-offs associated with the UA trade-off, performance paths, or stretch code HERS score requirements while also providing a compliance score that is calibrated with energy consumption and

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[2] NMR Group, Inc. *Residential Single-Family Building Department Document Review-Final Report.* Prepared for the Massachusetts Electric and Gas Program Administrators. December 1, 2015.

energy efficiency. This issue was considered when developing the MA-REC approach, though the effort required to resolve this issue was outside of the scope for this particular study.

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Section 1 Introduction

The Massachusetts Program Administrators (PAs) and Energy Efficiency Advisory Council (EEAC) Consultants began planning a study to measure single-family code compliance and baseline characteristics in December of 2014. The PAs and EEAC, along with NMR Group, Inc. and Dorothy Conant (from here on referred to as "the Team"), held three planning calls to develop the scope of the study, which was ultimately defined in the final Stage three detailed evaluation work plan.[3] This report, separated into five volumes, presents the results of evaluation activities, including 194 on-site visits of single-family homes in Massachusetts.

1.1 Reporting Organization

Given the amount of information covered in this study, the Team, PAs, and EEAC consultants agreed to provide the results in five separate report volumes:

Volume 1: Sampling, Recruitment, and On-site Data Collection

This report volume presents the sampling, recruitment, and on-site data collection methods.

Volume 2: Data Analysis Findings

This report volume presents detailed findings from the on-site inspections.

Volume 3: Baseline Findings

This report volume provides a high-level summary of the data analysis findings.

Volume 4: Compliance Findings

This report volume focuses on the code compliance assessment, which is founded in the data presented in the data analysis report volume.

Volume 5: UDRH Addendum

This report volume presents the updated Residential New Construction (RNC) programs' User Defined Reference Home (UDRH).

This document represents Volume 3: Baseline Findings.

1.2 Study Objectives and Background

This study was designed to meet the following primary goals:

- To provide the PAs and EEAC Consultants with a code compliance assessment of newly constructed single-family homes permitted at the end of the 2009

[3] NMR Group, Dorothy Conant, and Cadmus. *Final Single-Family New Construction Compliance/Baseline Study: Evaluation Plan.* Prepared for the Electric and Gas Program Administrators of Massachusetts. May 12, 2015.

International Energy Conservation Code (IECC) cycle, homes permitted during the beginning of the 2012 IECC cycle, and homes permitted under the stretch code

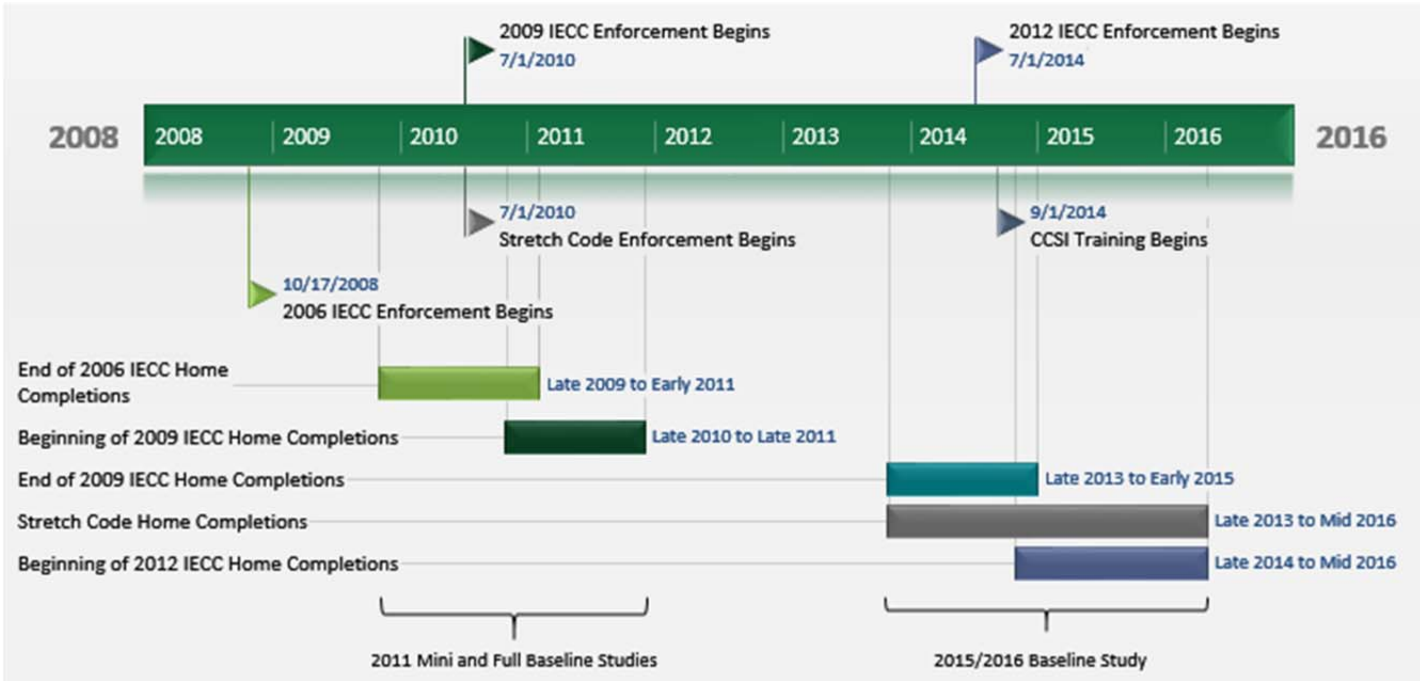
- To provide the information needed to update the UDRH for the low-rise component (residential buildings three stories or lower) of the RNC program

To meet the primary goals of the study and answer the research questions listed below, the PAs and EEAC Consultants decided to conduct on-site inspections with non-program single-family homes. This is consistent with the approach that has historically been used in Massachusetts to conduct code compliance assessments and update the RNC UDRH.

The code compliance assessments were conducted to provide support for the PAs' Code Compliance Support Initiative (CCSI). The CCSI seeks to claim savings from enhancing compliance with the energy code throughout Massachusetts. The PAs previously measured compliance with homes built at the end of the 2006 IECC and the beginning of the 2009 IECC cycles.[4] The inclusion of homes built at the end of the 2009 IECC cycle, the beginning of the 2012 IECC cycle, and homes built under the stretch code provides the PAs with a rich set of time series data that can be used to assess the potential savings from compliance enhancement efforts and the proportion of those savings that are attributable to the PAs' CCSI. Figure 1 presents the timing of the various code compliance cycles and also shows the range of construction completion dates for homes that have been included in the PAs' single-family compliance/baseline studies.

[4] NMR Group, Inc. *Code Compliance Results for Single-Family Non-Program Homes in Massachusetts.* Submitted to the Massachusetts Electric and Gas Program Administrators. September 2, 2014.

Figure 1: Timeline of Compliance Cycles and On-site Visit Home Completions



To leverage economies of scale, the Team, PAs, and EEAC Consultants decided to use this study to update the RNC programs' UDRH in conjunction with the aforementioned compliance assessment. The previous UDRH was completed in 2011 and is outdated, as it was based on homes built at the beginning of the 2009 IECC cycle.[5] The Team will work with the PAs and EEAC Consultants, along with other key stakeholders, to review the findings from this study and determine which results should be used to update the UDRH.

1.2.1 Research Questions

This study was designed to answer the following research questions:

- What are the code compliance levels of single-family homes built at the end of the 2009 IECC cycle, homes built at the beginning of the 2012 IECC cycle, and homes recently built under the stretch code?
- What above-code energy components are found in homes?
- What are the baseline characteristics of homes built in this period? How does that differ in stretch communities and for different code periods?
- How does compliance vary between stretch code and non-stretch code communities?
- In non-stretch code communities, how does compliance vary across the compliance paths (i.e., prescriptive, UA[6] trade-off, and performance)?
- How have compliance levels changed over time?
- What are the efficiency characteristics of homes' thermal envelopes (e.g., insulation, air leakage, duct leakage)?
- What are the efficiency-related characteristics of homes' heating, cooling, and water heating equipment?
- What are the efficiency-related characteristics of homes' other features, such as lighting and appliances?

1.3 Focus on 2012 IECC and Stretch Code Homes

The focus of this particular report volume (Volume 3) is to inform the development of a new UDRH for the RNC program, to show how study homes compare to RNC program homes, and to show how single-family new construction has changed over time in Massachusetts. To meet these goals, the Team has limited the presentation of data from the on-site inspections to represent only homes built at the beginning of the 2012 IECC cycle and homes built under the stretch code for this report volume. There are a couple of reasons for this:

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[5] NMR Group, KEMA, Cadmus, and Dorothy Conant. *Massachusetts 2011 Baseline Study of Single-Family Residential New Construction.* Submitted to Berkshire Gas, Cape Light Compact, Columbia Gas of Massachusetts, National Grid, New England Gas Company, NSTAR Electric & Gas, Until, and Western Massachusetts Electric Company. August 16, 2012.

[6] U-factor*area.

- To update the UDRH, the Team and PAs' have agreed that using the results of the most recently built baseline study homes (i.e., 2012 IECC and stretch code homes) is the most appropriate approach.
- The 2015 MA RNC program primarily consisted of homes built at the beginning of the 2012 IECC cycle and homes built under the stretch code. Comparing non-program homes to program homes built in the same code cycles results in the most up-to-date and realistic representation of what is currently taking place in the market.

The baseline study inspection results for homes built at the end of the 2009 IECC cycle and for all of the inspected homes are included in Volume 2: Data Analysis Findings.

1.4 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. As a result of this study, the evaluation team is able to utilize actual coefficients of variation to estimate the final precision levels of key home characteristics.

The coefficient of variation is of central importance to determining the final precision levels. A primary objective of this study is to document the existing building and equipment status of new single-family homes by feature. Some features are far more variable than others. In the current study, duct leakage and air infiltration are the most variable, and HVAC system efficiencies are the least variable.

The tables below show 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. There are three tables, Table 1 addresses the 2012 IECC sample homes that included 50 full-inspections and 50 diagnostic testing only inspections, Table 2 addresses the sample of 46 stretch code homes, and Table 3 addresses the combined sample of 2012 IECC and stretch code homes.

Relative precisions range from ± 0.9% to ± 5.4% at the 90% confidence level for all measures except air infiltration and duct leakage for all three samples.

Table 1: 2012 IECC Sample: Coefficients of Variation and Relative Precision

Parameter	Sample Size	Coefficient of Variation	Relative Precision
All Fossil-Fuel Fired Heating System AFUE	68	0.07	±1.4%
Central Air Conditioning SEER	64	0.05	±1.0%
Conditioned/Ambient Wall Insulation R Value	50	0.09	±2.0%
HERS Score	50	0.13	±3.0%
Cathedral Ceiling Insulation R-Value	31	0.18	±5.4%
Flat Ceiling Insulation R-Value	48	0.18	±4.2%
Air Infiltration—Air Changes per Hour at 50 Pascals	98	0.39	±6.3%
Duct Leakage to Outside—CFM25/100 Sq. Ft.	98	0.86	±14.1%
Total Duct Leakage—CFM25/100 Sq. Ft	98	0.65	±11.0%

Table 2: Stretch Code Sample: Coefficients of Variation and Relative Precision

Parameter	Sample Size	Coefficient of Variation	Relative Precision
All Fossil-Fuel Fired Heating System AFUE	58	0.05	±1.0%
Central Air Conditioning SEER	61	0.05	±1.1%
Conditioned/Ambient Wall Insulation R Value	46	0.13	±3.1%
HERS Score	46	0.20	±4.8%
Cathedral Ceiling Insulation R-Value	29	0.18	±5.4%
Flat Ceiling Insulation R-Value	41	0.18	±4.6%
Air Infiltration—Air Changes per Hour at 50 Pascals	46	0.42	±10.1%
Duct Leakage to Outside—CFM25/100 Sq. Ft.	43	1.19	±29.7%
Total Duct Leakage—CFM25/100 Sq. Ft	42	0.86	±22.0%

Table 3: Combined 2012 IECC and Stretch Code Sample: Coefficients of Variation and Relative Precision

Parameter	Sample Size	Coefficient of Variation	Relative Precision
All Fossil-Fuel Fired Heating System AFUE	126	0.06	±0.9%
Central Air Conditioning SEER	125	0.05	±0.7%
Conditioned/Ambient Wall Insulation R Value	96	0.13	±2.2%
HERS Score	96	0.17	±2.8%
Vaulted Ceiling Insulation R-Value	60	0.18	±3.1%
Flat Ceiling Insulation R-Value	89	0.19	±3.3%
Air Infiltration—Air Changes per Hour at 50 Pascals	144	0.4	±5.3%
Duct Leakage to Outside—CFM25/100 Sq. Ft.	141	0.98	±13.2%
Total Duct Leakage—CFM25/100 Sq. Ft	140	0.73	±10.0%

Conducting diagnostic only (duct blaster and blower door testing) inspections at an additional 50 2012 IECC homes improved the relative precision of both air infiltration and duct leakage estimates. As shown in Table 4, the sample size increase resulted in the relative precision of air infiltration (ACH50) improving from ±10.1% to ±5.3%, the relative precision of duct leakage to the outside improving from ±29.7% to ±13.2% and the relative precision of total duct leakage improving from ±22.0% to ±10.0%.

Table 4: Air and Duct Leakage Relative Precision

Relative Precision at the 90% Confidence Level			
Sample	Air Infiltration—Air Changes per Hour at 50 Pascals	Duct Leakage to Outside—CFM25/100 Sq. Ft.	Total Duct Leakage—CFM25/100 Sq. Ft
Stretch Code Homes	±10.1% (n=46)	±29.7% (n=43)	±22.0% (n-42)
2012 IECC Homes	±6.3% (n=98)	±14.1% (n=98)	±11.0% (n=98)
Combined 2012 IECC & Stretch Code	±5.3% (n=144)	±13.2% (n-141	±10.0% (n=140)

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Section 2 Preliminary UDRH Inputs

The 2015 Baseline UDRH input data are based on study findings. This section presents detailed tables showing the data that will be used to develop final UDRH inputs. For each UDRH input the tables show the number of observations and both weighted (WAV) and unweighted (Raw Data) averages for 2012 IECC homes, stretch code homes. and 2012 IECC and stretch code homes combined. Cases where the difference between 2012 IECC and stretch code data is statistically significant at the 90% confidence level are noted in the far-right column in red text.

Program Administrators will review this UDRH and develop a final set of UDRH inputs.

For conditioned/ambient walls, ceilings, and floors, U-values are addressed. U-values are the overall heat transfer coefficient for the entire wall, floor, or ceiling assembly, not just the insulation. The lower the U-value is, the more energy efficient the assembly. U-values were calculated using REM/Rate software and 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 5: Water Heating UDRH Input Information

WATER HEATING UDRH INPUTS		Code is Federal Standards									
ALL TYPE, SIZES, EXTRA INSULATION AND LOCATIONS ARE THE SAME AS THE RATED HOME	Current Inputs	2012 IECC Sample			Stretch Code Sample			Combined 2012 IECC & Stretch Code Samples			2012 IECC / Stretch Code Differences Statistically Significant
		Systems (n)	WAV EF	Raw Avg. EF	Systems (n)	WAV EF	Raw Avg. EF	Systems (n)	WAV EF	Raw Avg. EF	
Conventional (Natural Gas)	.67 EF .81 RE*	16	0.64	0.64	9	0.68	0.68	25	0.64	0.65	Sample Too Small to Test
Conventional (Propane)	.67 EF .81 RE	4	0.62	0.62	6	0.66	0.66	10	0.64	0.64	Sample Too Small to Test
Conventional (Natural Gas & Propane)		20	0.63	0.64	15	0.67	0.67	35	0.64	0.65	Significant
Conventional (Oil)	.67 EF .81 RE	No Baseline Homes									
Conventional (Electric)	.90 EF .98 RE	6	0.91	0.92	8	0.87	0.89	14	0.89	0.90	Sample Too Small to Test
Instantaneous converted to conventional (Natural Gas)	.67 EF .81 RE	10	0.93	0.92	9	0.91	0.92	19	0.93	0.92	Sample Too Small to Test

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WATER HEATING UDRH INPUTS		Code is Federal Standards									
ALL TYPE, SIZES, EXTRA INSULATION AND LOCATIONS ARE THE SAME AS THE RATED HOME	Current Inputs	2012 IECC Sample			Stretch Code Sample			Combined 2012 IECC & Stretch Code Samples			2012 IECC / Stretch Code Differences Statistically Significant
		Systems (n)	WAV EF	Raw Avg. EF	Systems (n)	WAV EF	Raw Avg. EF	Systems (n)	WAV EF	Raw Avg. EF	
Instantaneous converted to conventional (Propane)	67 EF .81 RE	5	0.92	0.94	3	0.85	0.86	8	0.91	0.91	Sample Too Small to Test
Instantaneous Natural Gas & Propane		15	0.92	0.92	12	0.90	0.91	27	0.91	0.91	Not Significant
Instantaneous converted to conventional (Oil)	67 EF .81 RE	No Baseline Homes									
Instantaneous converted to conventional (Electric)	.90 EF .98 RE	No Baseline Homes									
Weighted Avg. Nat. Gas and Propane Conventional and Instantaneous (weighting based on percent of conventional and instantaneous systems) n= 62 Avg. EF = 0.75 weighted and 0.77 unweighted											
Weighted Avg. Nat. Gas and Propane Conventional and Instantaneous (weighting based on percent of conventional and instantaneous systems)		35	0.74	0.76	27	0.76	0.78	62	0.75	0.77	Not Significant
Integrated** (Natural Gas)	.84 EF .898 RE	2	0.87	0.87	4	0.87	0.87	6	0.87	0.87	Sample Too Small to Test
Integrated (Propane)	.84 EF .898 RE	0	n/a	n/a	1	0.88	0.88	1	0.88	0.88	n/a
Integrated (Natural Gas & Propane)		2	0.87	0.87	5	0.87	0.87	7	0.87	0.87	Sample Too Small to Test
Integrated (Oil)	.79 EF .859 RE	No Baseline Homes									
Heat Pump Converted to Conventional (Electric)	.90 EF .98 RE	7	2.73	2.65	6	2.53	2.75	13	2.66	2.69	Sample Too Small to Test
Ground Source Heat Pump converted to conventional (Electric)	.90 EF .98 RE	No Baseline Homes									

* Recovery rate or recovery efficiency

**Indirect water heating system—storage tank integrated with boiler heating system.

Table 6: Heating UDRH Input Information

HEATING UDRH INPUTS		Code is Federal Standard									
ALL TYPE, SIZES, AUXILARY POWER AND LOCATIONS ARE THE SAME AS THE RATED HOME	Current Inputs	2012 IECC Sample			Stretch Code Sample			Combined 2012 IECC & Stretch Code Samples			2012 IECC / Stretch Code Differences Statistically Significant
		Systems (n)	WAV Efficiency	Raw Avg. Efficiency	Systems (n)	WAV Efficiency	Raw Avg. Efficiency	Systems (n)	WAV Efficiency	Raw Avg. Efficiency	
Combined appliance (oil)	.82 CAafue, .79 CAef	No Baseline Homes									
Air Source Heat Pump & Ductless Mini Splits	8.9 HSPF	5	10.01	9.92	8	10.28	10.38	13	10.18	10.20	Sample Too Small to Test
Ground Source Heat Pump (converted to an Air Source Heat Pump)	8.9 HSPF (2.61 COP)	0	n/a	n/a	1	4 COP	4 COP	1	4 COP	4 COP	n/a
Dual Fuel Heat Pump	7.7 HSPF, 91.7 AFUE	No Baseline Homes									
All Gas Furnaces Natural Gas & Propane		61	94.23	94.13	51	94.12	93.78	112	94.2	93.97	Not Significant
Non-Attic Gas Furnaces Natural Gas & Propane		46	95.05	94.75	36	95.08	94.96	82	95.06	94.84	Not Significant
Attic Gas Furnaces Natural Gas & Propane		15	92.14	92.21	15	91.33	90.96	30	91.9	91.59	Not Significant
All Oil Furnaces		0	n/a	n/a	1	83.9	83.9	1	83.9	83.9	n/a
Gas Boilers Nat. Gas & Propane		3	92.6	91.0	6	95.05	94.95	9	93.88	93.63	Sample Too Small to Test
Oil Boilers		1	85.3	85.3	0	n/a	n/a	1	85.3	85.3	n/a

HEATING UDRH INPUTS		Code is Federal Standard									
ALL TYPE, SIZES, AUXILARY POWER AND LOCATIONS ARE THE SAME AS THE RATED HOME	Current Inputs	2012 IECC Sample			Stretch Code Sample			Combined 2012 IECC & Stretch Code Samples			2012 IECC / Stretch Code Differences Statistically Significant
		Systems (n)	WAV Efficiency	Raw Avg. Efficiency	Systems (n)	WAV Efficiency	Raw Avg. Efficiency	Systems (n)	WAV Efficiency	Raw Avg. Efficiency	
Fuel fired, air distribution (natural gas)	91.7 AFUE	39	93.93	93.83	41	93.83	93.69	80	93.89	93.76	Not Significant
Fuel fired, hydronic distribution (natural gas)	84.3 AFUE	1	96.00	96.00	0	n/a	n/a	1	96.00	96.00	n/a
Fuel fired, air distribution (propane)	91.7 AFUE	24	94.54	94.14	16	94.77	94.46	40	94.63	94.27	Not Significant
Fuel fired, hydronic distribution (propane)	84.3 AFUE	No Baseline Homes									
Fuel fired air distribution (natural gas and propane)		63	94.15	93.95	57	94.21	93.91	120	94.17	93.93	Not Significant
Fuel fired, hydronic distribution (natural gas and propane)		1	96.00	96.00	0	n/a	n/a	1	96.00	96.00	n/a
Fuel fired, air distribution (oil)	84.1 AFUE	0	n/a	n/a	1	83.9	83.9	1	83.9	83.9	n/a
Fuel fired, hydronic distribution (oil)	82.0 AFUE	No Baseline Homes									
Combined appliance (natural gas)	.843 CAafue, .84 CAef	No Baseline Homes									
Combined appliance (propane)	.843 CAafue, .85 CAef	1	.95 CAafue	.95 CAafue	1	.95 CAafue	.95 CAafue	2	.95 CAafue	.95 CAafue	Sample Too Small to Test

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Table 7: Cooling UDRH Input Information

COOLING UDRH INPUTS		Code is Federal Standard									
ALL TYPE, SIZES AND LOCATIONS SAME AS RATED HOME	Current Inputs	2012 IECC Sample			Stretch Code Sample			Combined 2012 IECC & Stretch Code Samples			2012 IECC / Stretch Code Differences Statistically Significant
		Systems (n)	WAV SEER	Raw Avg. SEER	Systems (n)	WAV SEER	Raw Avg. SEER	Systems (n)	WAV SEER	Raw Avg. SEER	
Air Conditioner	13.7 SEER	64	13.3	13.4	61	13.4	13.5	125	13.4	13.4	Not Significant
Air Source Heat Pump*	13.7 SEER	6	18.3	17.8	8	18.4	19.0	14	18.4	18.5	Sample Too Small to Test
Ground Source Heat Pump	13.7 EER	0	n/a	n/a	1	23	23	1	23	23	n/a
Combined Air Conditioners & ASHPs		70	13.8	13.8	69	14.4	14.1	13.9	14.0	13.9	Not significant

*Includes three ductless mini splits with an average SEER of 20.

Table 8: Wall UDRH Input Information

Walls		2012 & 2015 IECC Code Requirement: R-20 or R-13 + R-5 c.i.* (UA Factor Alternative: 2012 Uo-.057, 2015 Uo-.060)									
Wall Type	Current Inputs	2012 IECC Sample			Stretch Code Sample			Combined 2012 IECC & Stretch Code Samples			2012 IECC / Stretch Code Differences Statistically Significant
		Homes (n)	WAV Uo	Raw Avg. Uo	Homes (n)	WAV Uo	Raw Avg. Uo	Systems (n)	WAV Uo	Raw Avg. Uo	
Above Grade Wall (Conditioned/Ambient)	Uo=.072	50	.063**	.063**	46	.060**	.062**	96	.062**	.062**	Significant for Weighted

*Continuous insulation.

**Less efficient than current prescriptive code.

Table 9: Floor UDRH Input Information

Floors		2012 & 2015 IECC Code Requirement: R-30 (U-Factor Alternative 2012 & 2015 IECC U-.033)									
Floor Type	Current Inputs	2012 IECC Sample			Stretch Code Sample			Combined 2012 IECC & Stretch Code Samples			2012 IECC / Stretch Code Differences Statistically Significant
		Homes (n)	WAV Uo	Raw Avg. Uo	Homes (n)	WAV Uo	Raw Avg. Uo	Homes (n)	WAV Uo	Raw Avg. Uo	
Frame Floor over Unconditioned Basement	Uo=.048	44	.045*	.048*	35	.045*	.045*	79	.045*	.047*	Significant for Raw Data

*Less efficient than current prescriptive code.

Table 10: Ceiling UDRH Input Information

Ceilings		2012 & 2015 IECC Code Requirement: R-49 (U-Factor Alternative 2012 & 2015 IECC U-.026)									
Ceiling Type	Current Inputs	2012 IECC Sample			Stretch Code Sample			Combined 2012 IECC & Stretch Code Samples			2012 IECC / Stretch Code Differences Statistically Significant
		Homes (n)	WAV Uo	Raw Avg. Uo	Homes (n)	WAV Uo	Raw Avg. Uo	Homes (n)	WAV Uo	Raw Avg. Uo	
Attic	Uo=.041	48	.029**	.029**	41	.030**	.032**	89	.030**	.030**	Significant for Raw Data
Vaulted*	Uo=.043	31	.040**	.039**	29	.035**	.037**	60	038**	.038**	Significant for Weighted

* If the design of the roof/ceiling assembly does not allow sufficient space for the required insulation, the minimum required insulation for such roof/ceiling assemblies shall be R-30. This reduction of insulation from the requirements of Section R402.1.2 shall be limited to 500 square feet (46 m2) or 20 percent of the total insulated ceiling area, whichever is less.

** Less efficient than current prescriptive code.

Table 11: Window UDRH Input Information

Windows		2012 & 2015 IECC Code Requirement: U-.30 (U-Factor Alternative 2012 & 2015 IECC U-.32)									
Orientation Distribution	Current Inputs	2012 IECC Sample			Stretch Code Sample			Combined 2012 IECC & Stretch Code Samples			2012 IECC / Stretch Code Differences Statistically Significant
		Homes (n)	WAV U/ SHGC	Raw U/ SHGC	Homes (n)	WAV U/ SHGC	Raw U/ SHGC	Homes (n)	WAV U/ SHGC	Raw U/ SHGC	
Equally distributed	U=.34	13	.29	.29	20	.32	.30	33	.30	.30	Not Significant
Equally distributed	SHGC=.346	13	.30	.29	20	.33	.31	33	.31	.30	Not Significant

Table 12: Foundation Wall UDRH Input Information

Foundation Walls		2012 & 2015 IECC Code Requirement: R-19 or R-15 c.i.* (U-Factor Alternative 2012 & 2015 IECC U-.055)									
Type	Current Inputs	2012 IECC Sample			Stretch Code Sample			Combined 2012 IECC & Stretch Code Samples			2012 IECC / Stretch Code Differences Statistically Significant
		Homes (n)	WAV R-Value	Raw Avg. R-Value	Homes (n)	WAV R-Value	Raw Avg. R-Value	Homes (n)	WAV R-Value	Raw Avg. R-Value	
Conditioned basement	8" solid concrete or stone walls with R-10.4 continuous insulation, grade 1, no studs	14	16.2	15.1	18	16.0	16.0	32	16.0	15.6	Not Significant
Unconditioned basement	10" thick concrete or stone walls with R-3.1 cavity insulation, grade 3, 2x4 studs at 16" O.C.	32	1.4	1.1	24	0.5	0.4	56	1.1	0.8	Significant

*Continuous insulation.

Table 13: Slab UDRH Input Information

Slabs		2012 & 2015 IECC Code Requirement: Unheated Slab- R-10, 2 ft. Heated Slab- R-15, 2 ft.									
Type	Current Inputs	2012 IECC Sample			Stretch Code Sample			Combined 2012 IECC & Stretch Code Samples			2012 IECC / Stretch Code Differences Statistically Significant
		Homes (n)	WAV R-Value	Raw Avg. R-Value	Homes (n)	WAV R-Value	Raw Avg. R-Value	Homes (n)	WAV R-Value	Raw Avg. R-Value	
Unheated slab, on grade	R-10 under slab (2ft), no perimeter insulation	4	0*	0*	10	3.0*	4.0*	14	1.9*	2.9*	Sample Too Small to Test
Unheated slab, below grade	R-10 under slab (2ft), no perimeter insulation										
Heated slab, on grade	R-15 under slab (2ft), no perimeter insulation	1	20	20	n/a	n/a	n/a	1	20	20	n/a
Heated slab, below grade	R-15 under slab (2ft), no perimeter insulation										

* Less efficient than current prescriptive code.

Table 14: Duct Insulation UDRH Input Information

Duct Insulation UDRH INPUTS											2012 & 2015 IECC Code Requirement: Attic Supply R-8, Other Unconditioned Space R-6
THE LOCATION IS THE SAME AS THE RATED HOME EXCEPT WHERE NOTED	Current Inputs	2012 IECC Sample			Stretch Code Sample			Combined 2012 IECC & Stretch Code Samples			2012 IECC / Stretch Code Differences Statistically Significant
Duct Type		Homes (n)	WAV R-Value	Raw Avg. R-Value	Homes (n)	WAV R-Value	Raw Avg. R-Value	Homes (n)	WAV R-Value	Raw Avg. R-Value	
Unconditioned Attic (supply only)	R-6.5	29	7.2*	7.1*	31	6.3*	6.6*	60	6.9*	6.9*	Significant
All other unconditioned spaces	R-5.5	45	6.1	6.1	35	5.1*	6.0	80	5.8*	6.0	Not Significant
Ducts in conditioned areas converted to unconditioned garage	R-30	Not Applicable									

* Less efficient than current prescriptive code.

Table 15: Duct Leakage to Outside UDRH Input Information

DUCT LEAKAGE to Outside (LTO) UDRH INPUT											2012 & 2015 IECC: No LTO Code Requirement Total Leakage of 4 CFM25/100 Sq. Ft. CFA Current Stretch Code Requirement: LTO ≤8 CFM25/100 Sq. Ft. CFA
DISTRIBUTION LOSS IS FOR DUCTED HOMES ONLY	Current Input	2012 IECC Sample			Stretch Code Sample			Combined 2012 IECC & Stretch Code Samples			2012 IECC / Stretch Code Difference Statistically Significant
		Homes (n)	WAV	Raw Avg.	Homes (n)	WAV	Raw Avg.	Homes (n)	WAV	Raw Avg.	
Leakage to the Outside	11.9 CFM per 100 sq. ft. @25Pa	98	3.9	3.9	43	3.6	4.1	141	3.8	3.9	Not Significant

Table 16: Air Infiltration UDRH Input Information

AIR INFILTRATION UDRH INPUTS					2012 & 2015 IECC Mandatory Requirement ≤3 ACH50					
ACH50	Current Input	2012 IECC Sample			Stretch Code Sample			Combined 2012 IECC & Stretch Code Samples			2012 IECC / Stretch Code Difference Statistically Significant
		Homes (n)	WAV ACH50	Raw Avg. ACH50	Homes (n)	WAV ACH50	Raw Avg. ACH50	Homes (n)	WAV ACH50	Raw Avg. ACH50	
Shelter class 4	4.48 ACH50	98	3.59*	3.50*	46	3.41	3.72	144	3.52*	3.57*	Not Significant

* Less efficient than current prescriptive code.

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Section 3 Building Envelope

The sections below present a summary of the building envelope components that were inspected as part of the on-site visits. As previously mentioned, this report volume focuses on homes built under the 2012 IECC and stretch code as these are the results that are most pertinent to the UDRH development and the comparison to program homes. A more detailed analysis for each component, along with results for, and a comparison to, homes built under the 2009 IECC, can be found in Volume 2: Data Analysis Findings.

Please note that within each of these sections we compare the baseline study results to prescriptive code requirements as a reference point. Stretch code homes are compared to the 2009 IECC prescriptive requirements as the current stretch code requirements build off the 2009 IECC. It is important to understand that builders often choose to comply with the code using a trade-off or performance approach that allows them to fall below the prescriptive requirements for certain measures. That said, while some homes may fall below the prescriptive requirement for certain measures, it does not necessarily mean the home is non-compliant. This issue is addressed in more detail in Volume 4: Code Compliance Findings.

3.1 Above-Grade Walls

This section focuses on the exterior walls (conditioned/ambient walls) of the homes included in the study. More detail on other wall locations can be found in Volume 2: Data Analysis Findings.

The average R-value of conditioned/ambient wall insulation in combined 2012 IECC and stretch code 2015 baseline homes (R-20.8 unweighted and R-21.0 weighted) is lower than in 2015 program homes (R-21.1) and higher than in the 2011 baseline study (R-19.4). Most 2012 IECC (74%) and stretch code (61%) homes meet or exceed the prescriptive code requirement of R-20. The average U-value of conditioned/ambient walls in combined 2012 IECC and stretch code 2015 baseline homes (U-0.062 unweighted and weighted) is higher (less efficient) than in 2015 program homes (U-0.060), but lower (more efficient) than the current UDRH input of U-0.072.

R-18 is the lowest average R-value seen in the homes, and R-41 is the highest (a stretch code home built with structural insulated panels, or SIPs). The average R-value of the exterior walls in homes varies only slightly across the code versions, with stretch code being significantly higher (weighted R-21.8) than 2012 IECC (weighted R-20.6) homes (Table 17). While this is a statistically significant difference, this difference falls away if the single R-41 SIP-based stretch code home is excluded from the analyses.

Table 17: Conditioned/Ambient Wall R-Values

R-Value (Average Value per House)	2012 IECC (n=50)	Stretch Code (n=46)	2012 IECC & Stretch Code (n=96)
Minimum	18	18	18
Maximum	31	41	41
Unweighted Average	20.7	20.9	20.8
Weighted Average	20.6[a]	21.8[a]	21.0
Median	21	21	21

[a] Statistically significant difference at the 90% confidence level.

Most homes (95%) have exterior walls that consist of 2x6 framing with 16 inch-on-center spacing. Only five homes have some other type of framing for the majority of their exterior walls: three homes with 2x4 framing, one with 2x6 framing at 24-inch on-center spacing, and one with SIP construction. Continuous insulation is the majority insulation method (by wall area) in only two homes, and they are both stretch code homes. One uses blown-in cellulose cavity insulation in 2x6 walls (R-19) with XPS rigid foam (R-5) as continuous insulation across the studs, and the other uses SIPs to achieve R-values higher than R-40. Cavity insulation is the main insulation method in all the other homes. Cavities are predominantly insulated with fiberglass batt insulation (92% of all 2012 IECC homes and 80% of all stretch code homes) and typically have a grade II insulation installation quality (84% of all 2012 IECC and stretch code homes combined).

Table 18 shows the margin by which average R-value compares to the prescriptive code standard.[7] The average wall R-values cluster close to the code requirements; 98% of the 2012 IECC and 93% of the stretch code homes (not a statistically significant difference) have average wall R-values less than 15% away from the prescriptive code requirement.[8]

Table 18: Conditioned/Ambient Walls – Average R-Value vs. Prescriptive Requirements

Avg. R-Value vs. Code	2012 IECC (n=50)		Stretch Code (n=46)	
30+% worse	0 (0%)	*Worse: 13 (26%)*	0 (0%)	*Worse: 18 (39%)*
15% to < 30% worse	0 (0%)		0 (0%)	
<15% worse	13 (26%)		18 (39%)	
At code (R-20 or R13+5)	**0 (0%)**		**1 (2%)**	
<15% better	36 (72%)[a]	*Better: 37 (74%)[c]*	24 (52%)[a]	*Better: 27 (59%)*
15% to < 30% better	0 (0%)		0 (0%)	
30+% better	1 (2%)		3 (7%)	

[a] Statistically significant difference at the 90% confidence level.

3.2 Ceilings

This section focuses on the flat ceilings (attics) of the homes included in the study. Details on vaulted ceilings can be found in Volume 2: Data Analysis Findings.

The unweighted average R-value of flat ceiling insulation in combined 2012 IECC and stretch code 2015 baseline homes (R-40.7) is slightly lower and the average weighted R-value (R-41.4) slightly higher than in 2015 program homes (R-41.0); both unweighted and weighted average R-values in the baseline homes are higher than in the 2011 baseline study (R-36.8). Just over one half (54%) of stretch code baseline homes meet or exceed the 2009 IECC prescriptive code requirement of R-38, and just over one quarter (27%) of 2012 IECC baseline homes meet or exceed the 2012 IECC prescriptive code requirement of R-49. The average U-value of flat ceilings in combined 2012 IECC and stretch code 2015 baseline homes (U-0.030 unweighted and weighted) is higher (less efficient) than in 2015 program homes (U-0.027), but lower (more efficient) than the current UDRH input of U-0.041.

It is important to note that the 2012 IECC resulted in an increased code requirement over the 2009 IECC for flat ceiling insulation from R-38 to R-49. The 2012 IECC homes have a significantly higher average R-value (R-43.3) than stretch code homes (R-37.6) (Table 19). The 2012 IECC homes (67%) and stretch code homes (61%) both consistently used

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[7] Homes using cavity insulation are compared to the R-20 requirement for cavity insulation, while the two homes using continuous insulation are compared to the R13+5 requirement.

[8] Significantly more 2012 IECC homes (72%) than stretch code homes (52%) have average wall R-values that fall just above code requirement (less than 15% better than the R-20 standard, due largely to many R-21 values), but the increased efficiency of these walls is quite minor.

continuous insulation on top of cavity insulation as the main insulation method in flat ceilings. When insulators use cavity and continuous insulation together, the insulation not only fills the cavity between framing members, but is installed deep enough to cover the tops of the attic rafters, reducing thermal bridging through the framing. Blown-in insulation products were fairly common in 2012 IECC and stretch code homes combined, where 73% of homes used either blown fiberglass (27%) or blown cellulose (46%). This resulted in 72% of homes having a Grade I insulation installation for flat attic ceilings.

Table 19: Flat Ceiling Characteristics

Flat Ceiling Insulation R-value	2012 IECC (n=48)	Stretch Code (n=41)	2012 IECC & Stretch Code (n=89)
Minimum	26	27	26
Maximum	65	54	65
Unweighted Average	43.3[a]	37.6[a]	40.7
Weighted Average	42.4[a]	39.4[a]	41.4
Median	42	38	38

[a] Statistically significant difference at the 90% confidence level.

Table 20 describes how the average flat ceiling R-values of stretch code homes compare to the prescriptive code level of R-38. Overall, 46% of stretch code homes have flat ceilings with average R-values below R-38, 22% are right at R-38, and 32% are above R-38. Flat ceilings are insulated to an average R-value within 15% of R-38 in 54% of stretch code homes.

Table 20: Flat Ceilings – Average R-Value vs. 2009 IECC/Stretch Code Prescriptive Requirements

Avg. R-Value vs. Code	Stretch Code (n=29)	
30+% worse	1 (2%)	*Worse: 19 (46%)*
15% to < 30% worse	10 (24%)	
<15% worse	8 (20%)	
At code (R-38)	**9 (22%)**	
<15% better	5 (12%)	*Better: 13 (32%)*
15% to < 30% better	5 (12%)	
30+% better	3 (7%)	

[a] Statistically significant difference at the 90% confidence level.

Table 21 shows how the average flat ceiling R-value of the 2012 IECC homes compares to the prescriptive code level of R-49: 73% are lower than R-49, and only 25% are better. Fifty-two percent have an average flat ceiling R-value within 15% of R-49. Only two 2012 IECC homes exceed the code level by 15% or more, and both use blown-in cellulose insulation; none of the 12 above-code homes use fiberglass batts. Of the 21 homes that fall below R-49 by 15% of more, nine are fiberglass batt installations, nine are cellulose, and three are blown-in fiberglass.

Table 21: Flat Ceilings – Average R-Value vs. 2012 IECC Prescriptive Requirements

Avg. R-Value vs. Code	2012 IECC (n=48)	
30+% worse	3 (6%)	*Worse: 35 (73%)*
15% to < 30% worse	18 (38%)	
<15% worse	14 (29%)	
At code (R-49)	**1 (2%)**	
<15% better	10 (21%)	*Better: 12 (25%)*
15% to < 30% better	1 (2%)	
30+% better	1 (2%)	

3.3 Frame Floors

This section focuses on the basement and crawl space ceilings (conditioned/unconditioned basement and conditioned/enclosed crawl space frame floors) of the homes included in the study. More detail on other floor locations can be found in Volume 2: Data Analysis Findings.

The average R-value of insulation in conditioned floors over unconditioned basements and crawl spaces in combined 2012 IECC and stretch code 2015 baseline homes (R-30.7 unweighted and R-31.1 weighted) is higher than in 2015 program homes (R-30.3) and higher than the average R-value of insulation in floors over unconditioned basements in the 2011 baseline study (R-26.7). Almost all 2012 IECC (98%) and stretch code (91%) homes meet or exceed the prescriptive code requirement of R-30. The average U-value of conditioned floors over unconditioned basements and crawl spaces in combined 2012 IECC and stretch code 2015 baseline homes (U-0.047 unweighted and U-0.045 weighted) is higher (less efficient) than in 2015 program homes (U-0.044), but lower (more efficient) than the current UDRH input of U-0.048.

Table 22 shows that homes built under the 2012 IECC (unweighted average R-31.5) have significantly higher R-values than stretch code homes (unweighted average R-29.7). Fiberglass batts are used in all of the homes' frame floors over basements, either alone or in combination with another material, such as mineral wool, and none of these frame floors use a spray-applied or blown-in material as their main insulation method. The highest average R-value seen, R-45, is a 2012 IECC home where fiberglass batts and mineral wool batts were layered together. None of the homes have any continuous insulation in the floors over the basements and crawl spaces; they are all insulated solely with cavity insulation. Only five percent of all 2012 IECC and stretch code homes combined have a Grade I insulation installation. The majority (71%) have a Grade II insulation installation, while 24% have a Grade III installation.

Table 22: Conditioned Floors over Unconditioned Basements and Crawl Spaces

	2012 IECC (n=44)	Stretch Code (n=35)	2012 IECC & Stretch Code (n=79)
Minimum	19	19	19
Maximum	45	38	45
Unweighted Average	31.5[a]	29.7[a]	30.7
Weighted Average	31.8[a]	29.6[a]	31.1
Median	30	30	30

[a] Statistically significant difference at the 90% confidence level.

Table 23 shows the margin by which average R-value compares to the R-30 code requirement (the same under both the 2012 IECC and stretch code). These basement ceilings clearly cluster right at the R-30 mark. In the 2012 IECC homes, 21% of these insulated basement ceilings are insulated higher than the code standard, a significantly higher rate than found in the stretch code homes (two homes, six percent).

Table 23: Floors Over Basements and Crawl Spaces – Average R-Value vs. Prescriptive Requirements

<table>
<tr><th>Avg. R-Value vs. Code</th><th colspan="2">2012 IECC (n=44)</th><th colspan="2">Stretch Code (n=35)</th></tr>
<tr><td>30+% worse</td><td>1 (2%)</td><td rowspan="3">Worse:
1 (2%)</td><td>2 (6%)</td><td rowspan="3">Worse:
3 (9%)</td></tr>
<tr><td>15% to < 30% worse</td><td>0 (0%)</td><td>1 (3%)</td></tr>
<tr><td><15% worse</td><td>0 (0%)</td><td>`0 (0%)</td></tr>
<tr><td>At code (R-30)</td><td colspan="2">34 (77%)</td><td colspan="2">30 (86%)</td></tr>
<tr><td><15% better</td><td>0 (0%)</td><td rowspan="3">Better:
9 (21%)[b]</td><td>0 (0%)</td><td rowspan="3">Better:
2 (6%)[b]</td></tr>
<tr><td>15% to < 30% better</td><td>8 (18%)[a]</td><td>2 (6%)[a]</td></tr>
<tr><td>30+% better</td><td>1 (2%)</td><td>0 (0%)</td></tr>
</table>

[a,b] Statistically significant difference at the 90% confidence level.

3.4 Windows

It is often difficult to verify the efficiency of windows on site as it is impossible to visually inspect for insulating gasses such as argon. As a result, the Team used building department documentation and window decals, as available, to document the performance characteristics of windows. Note that these data are frequently based on a single value per site, so it is difficult to make certain generalizations about window characteristics such as whether windows were selected to accommodate changes in performance by orientation, or even whether prescriptive code requirements are being met. However, the available data suggest that more than 90% of homes meet the prescriptive requirements for window performance (i.e., U≤0.32 for 2012 IECC and U≤0.35 for Stretch Code).[9]

The estimated average U-value of windows in combined 2012 IECC and stretch code 2015 baseline homes (U-0.30 unweighted and weighted) is lower (better) than in the 2011 baseline study (U-0.34) and lower than the current UDRH input of U-0.34.

There is very little variation in window efficiency across the code groups and the overall average for all homes was a U-factor of 0.30 (Table 24).

Table 24: Window U-factor by Code

Window U-factor	2012 IECC (n=13)	Stretch Code (n=20)	2012 IECC & Stretch Code (n=33)
Minimum	0.21	0.24	0.21
Maximum	0.31	0.46	0.46
Unweighted Average	0.29	0.30	0.30
Weighted Average	0.29	0.32	0.30
Median	0.29	0.30	0.30

Interestingly, the Team found that there are significantly more homes oriented to the East than other directions, especially a North–South orientation, which reduces summer solar loads while maximizing winter solar gains.[10] There is also a statistically significant dearth of homes oriented toward the Northwest. Consequently, the average home has relatively little Southern-facing window area (only 28% of all window area).[11]

3.5 Foundation Walls

As in previous baseline studies, the foundation wall analysis only assesses homes with foundation walls in conditioned space. The energy code does not require foundation walls to be insulated in homes with unconditioned basements because the thermal boundary in those homes is typically the frame floor. The 2009 IECC prescriptive requirement is R-10 continuous or R-13 cavity insulation, and the 2012 IECC prescriptive code requirement is R-15 continuous or R-19 cavity insulation.

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[9] Of the homes with data available for these properties, one site for each of the three building codes did not meet the prescriptive requirement, but these homes were constructed using either UA trade-off (2009 & 2012 IECC) or performance path (Stretch Code).

[10] "Building Energy Resources Center: Site Planning - Lot Orientation," *U.S. Department of Energy*, Feb. 1 2012, http://resourcecenter.pnl.gov/cocoon/morf/ResourceCenter/article//1401 via https://www.energycodes.gov/sites/default/files/documents/ta_site_planning-lot_orientation.pdf

[11] Southern-facing includes windows oriented to the southeast and southwest.

The average R-value of insulation on foundation walls in conditioned spaces in combined 2012 IECC and stretch code 2015 baseline homes (R-15.6 unweighted and R-16.0 weighted) is higher than in 2015 program homes (R-14.8) and higher than in the 2011 baseline study (R-12.7). Most stretch code homes with foundation walls in conditioned space in the current baseline study (83%) exceeded the 2009 IECC-based code requirement of R-10 continuous or R-13 cavity insulation. Less than one half of 2012 IECC baseline homes with foundation walls in conditioned space (43%) met or exceeded the 2012 IECC prescriptive code requirement of R-15 continuous or R-19 cavity insulation. Average foundation wall insulation in conditioned space for combined stretch code and 2012 IECC baseline homes is higher than the current UDRH input of R-10.4 continuous insulation.

Interior cavity insulation is the predominant method for insulating foundation walls, typically with fiberglass batts. One-third of homes (33%) have conditioned basements. There is no statistically significant difference between weighted or unweighted average R-values between 2012 IECC and stretch code homes (Table 25).

Table 25: Conditioned Basement Foundation Insulation Across Codes

Effective Foundation Wall Insulation R-value	2012 IECC (n=14)	Stretch Code (n=18)	2012 IECC & Stretch Code (n=32)
Minimum	0	10	0
Maximum	33	30	33
Unweighted Average	15.1	16.0	15.6
Weighted Average	16.2	16.0	16.0
Median	16.6	15.5	16.0

Most homes built under stretch code (83%) exceed the 2009 IECC prescriptive requirement of R-10 continuous insulation or R-13 cavity insulation (Table 26).

Table 26: Comparison of 2009 IECC Based Stretch Code Homes to Prescriptive Code Requirements

2009 IECC Prescriptive Code R-10/13	Stretch Code (n=18)
Less than R-10/13	3 (17%)
R-10/13	–
More than R-10/13	15 (83%)

More than one-half of the homes (57%) built at the beginning of the 2012 IECC cycle do not meet the 2012 IECC prescriptive code requirement of R-15 continuous insulation or R-19 cavity insulation (Table 27). Interestingly, 72% of homes built under the stretch code (which is based on the 2009 IECC) meet or exceed the 2012 IECC prescriptive foundation wall insulation requirement.

Table 27: Comparison of 2012 IECC Homes to Prescriptive Code Requirements

2012 IECC Prescriptive Code R-15/19	2012 IECC (n=14)
Less than R-15/19	8 (57%)
R-15/19	1 (7%)
More than R-15/19	5 (36%)

3.6 Slabs

Auditors collected information about slab insulation through review of building department documents, code compliance certificates, discussions with homeowners, and personal copies of building plans. Unfortunately, slab insulation details were unavailable for the majority of homes (59%), and they are impractical to ascertain once a slab is poured.

The average R-value of slab insulation in combined 2012 IECC and stretch code 2015 baseline homes where the R-value of slab insulation was confirmed or reasonably estimated (R-4.0 unweighted and R-2.6 weighted) is lower than current UDRH inputs of R-10 under slab insulation for unheated slabs and R-15 for heated slabs. Out of the 15 2012 IECC and stretch code baseline homes where the R-value of slab insulation was confirmed or reasonably estimated, slabs in only five homes (one 2012 IECC and four stretch code) met prescriptive code requirements.

Table 28 presents the average R-values of slab insulation that was confirmed or reasonably estimated during the on-site inspections.

Table 28: Known Slab Insulation R-values Across Codes

Slab Insulation R-value	2012 IECC (n=5)	Stretch Code (n=10)	2012 IECC & Stretch Code (n=15)
Minimum	0	0	0
Maximum	20	10	20
Unweighted Average	5.0	4.0	4.0
Weighted Average	2.0	3.0	2.6
Median	0	0	0

4

Section 4 Mechanical Equipment

This section focuses on the primary heating, cooling, and water heating equipment that was found in 2012 IECC and stretch code homes. More details on mechanical equipment can be found in Volume 2: Data Analysis Findings.

4.1 HEATING EQUIPMENT

There is no specific code requirement for heating system efficiency, but there are federal standards. Current federal standards are AFUE 80 for gas furnaces, AFUE 83 for oil furnaces, AFUE 82 for gas-fired hot water boilers and AFUE 84 for oil-fired hot water boilers. All natural gas, propane and oil furnaces and boilers in inspected homes met or exceeded current federal AFUE standards.

The overall average unweighted AFUE of fossil fuel systems in combined 2012 IECC and stretch code baseline homes (AFUE 93.3) is higher than in the 2011 baseline study (AFUE 90.9). The average AFUEs for all types of primary heating systems observed in 2012 IECC and stretch code 2015 baseline homes are higher than current UDRH inputs, with one exception—one 2015 baseline home had an oil furnace and the AFUE of that oil furnace was 83.9, which is slightly lower than the current UDRH input of AFUE 84.1 for an oil-fired air distribution heating system. All air source heat pump heating systems meet federal standards, and the average Heating Season Performance Factor (HSPF) of these systems in combined 2012 IECC and stretch code baseline homes (HSPF 10.20 unweighted and HSPF 10.18 weighted) is higher than the current UDRH input of HSPF 8.9.

Most homes (94%) have natural gas (64%) or propane (30%) heating systems. The only statistically significant difference in primary heating fuels from the 2011 baseline is the drop in the percentage of homes with oil heating systems, which dropped from 13% in the 2011 baseline study to two percent in the 2015 study. Most homes (84%) have furnaces, nine percent have boiler-based heating systems, one has a ducted air source heat pump, one a ground source heat pump, and one uses a wood stove as the primary heat source. There are no statistically significant differences from the 2011 baseline in the percentages of the different types of heating systems in inspected homes. However, the 2015 study is the first time an inspected home had a ducted air source heat pump as the primary heating system.

Only 22% of 113 furnaces in inspected homes have an electronically commutated motor (ECM). An ECM motor is a brushless DC motor that offers efficiency gains relative to the industry standard permanent split capacitor (PSC) motor. ECMs offer two major advantages over PSC motors. First, ECMs use significantly less electricity than PSC motors while producing comparable air flow. Second, ECMs are variable speed motors with the flexibility to adjust air flow depending on the demand being called for by the furnace or central air conditioning system. Not all ENERGY STAR-qualified furnaces have ECM motors—some have multi-speed fans but not fully variable ECMs. Overall, 25 furnaces have ECM motors and are variable speed, 81 furnaces have multi-speed fans and seven furnaces have single speed fans.

Table 29 shows the average weighted and unweighted AFUE for furnaces and boilers in 2012 IECC and stretch code homes. All average AFUE are higher than in the 2011 baseline study except the AFUE of the one oil boiler in the 2015 study (85.3) is slightly lower than the average AFUE of six oil boilers in the 2011 study (85.9).

Table 29: Furnace and Boiler Efficiency

Heating System Efficiency (AFUE) 2012 IECC & Stretch Code Homes	Number of Heating Systems	Weighted Average AFUE	Unweighted Average AFUE
Natural Gas & Propane Furnaces	112	94.2	94.0
Non-Attic Gas Furnaces Natural Gas & Propane	82	95.1	94.8
Attic Gas Furnaces Natural Gas & Propane	30	91.9	91.6
Oil Furnaces	1	83.9	83.9
Gas Boilers Nat. Gas & Propane	9	93.9	93.6
Oil Boilers	1	85.3	85.3

Only 20% of heating systems in the 2012 IECC and stretch code homes inspected are ENERGY STAR qualified. This is far less than in the 2011 baseline study in which 80% of fuel-fired heating equipment was ENERGY STAR qualified. However, there is an explanation for this drop. ENERGY STAR criteria for the northern states have changed since the 2011 study from 90 AFUE to 95 AFUE for gas furnaces, from 85 AFUE to 90 AFUE for gas boilers, and from to 85 AFUE to 87 AFUE for oil boilers. The ENERGY STAR criteria for oil furnaces remained at 85 AFUE. One home has a ducted air source heat pump as the primary heating system and one has a ground source heat pump—both systems are ENERGY STAR qualified.

Proper sizing of HVAC systems is important to ensure that systems operate efficiently and maximize occupant comfort. Improperly sized equipment may have reduced life spans due to short-cycling, or risk damage to the home from mold growth due to inadequate moisture removal. Manual J is the recognized method for calculating heating system sizes. As shown in Table 30, most homes have oversized heating equipment. Only nine percent of inspected 2012 IECC and stretch code homes complied with Manual J sizing criteria.

Table 30: Manual J Heating Compliance

Heating Capacity to Heat Load Ratio	2012 IECC (n=50)	Stretch Code (n=46)	2012 IECC & Stretch Code (n=96)
Complies (≤ 140%)	3 (6%)	6 (13%)	9 (9%)
Fails (≤ 160%)	1 (2%)	8 (17%)	9 (9%)
Fails (≤ 280%, Manual J×2)	38 (76%)	28 (61%)	66 (69%)
Fails (>280%)	8 (16%)	4 (9%)	12 (13%)

4.2 COOLING EQUIPMENT

There is no specific code requirement for cooling system efficiency, but there are federal standards. Current federal standards (effective for equipment manufactured on or after January 1, 2015) are SEER 13 for split-system air conditioners and SEER 14 (an increase from SEER 13 for equipment manufactured prior to January 1, 2015) for split-system heat pumps, single-package air conditioners, and heat pumps. All cooling systems in inspected homes met or exceeded federal standards in place when the equipment was manufactured.

The overall average SEER of central air conditioning systems in combined 2012 IECC and stretch code baseline homes (SEER 13.9) is higher than in the 2011 baseline study (SEER 13.6). The average SEER for central air conditioners in combined 2012 IECC and stretch code 2015 baseline homes (SEER 13.4 unweighted and weighted) is slightly lower than the current UDRH input of SEER 13.7. The average SEER for ASHPs in 2012 IECC and stretch code 2015 baseline homes (SEER 18.5 unweighted and 18.4 weighted) is higher than the current UDRH input of SEER 13.7.

Almost all inspected 2012 IECC and stretch code homes (97%) have some type of primary cooling equipment. Not much has changed between the 2011 and 2015 baseline studies. As shown in Table 31, central air conditioning systems remain the dominant system type. However, three homes in the 2015 study have ducted air source heat pump central cooling systems and two homes have ductless mini splits—no 2011 study homes had air source heat pump cooling systems.

Table 31: Primary Cooling System Type
(Base: All homes)

Type	IECC 2012 (n=50)	Stretch Code (n=46)	2012 IECC & Stretch (n=96)
Central air conditioner	45 (90%)	39 (86%)	84 (88%)
Room air conditioner		3 (7%)	3 (3%)
Ducted ASHP	2 (4%)	1 (2%)	3 (3%)
Ductless mini-split	--*	2 (4%)	2(2%)
GSHP-closed loop	--	1 (2%)	1 (1%)
None	3 (6%)	--	3 (3%)

* Two homes had supplemental Ductless Mini-Splits that are not included in this count

The overall efficiency of cooling systems has hardly changed since the 2011 study. The weighted and unweighted average SEER of central air conditioner systems in the 2015 study is 13.4, down slightly from 13.7 in the 2011 study. Table 32 shows that only ten percent of the 125 central air conditioning systems in inspected 2012 IECC and stretch code homes are ENERGY STAR qualified, but all ten ductless mini splits (in three homes) and two out of four ducted air source heat pumps in inspected homes are ENERGY STAR qualified.[12]

[12] One 2012 IECC home has two 9.3 HSPF non-ENERGY STAR ASHP systems

Table 32: Cooling Equipment ENERGY STAR Status by Type

ENERGY STAR Status	2012 IECC (n=71)	Stretch Code (n=74)	2012 IECC & Stretch (n=145)
Central air conditioning	***64 (100%)***	***61 (100%)***	***125 (100%)***
Yes	4 (6%)	8 (13%)	12 (10%)
No	60 (94%)	53 (87%)	113 (90%)
Ducted ASHP	*3 (100%)*	*1 (100%)*	*4 (100%)*
Yes	1 (33%)	1 (100%)	2 (50%)
No	2 (67%)	--	2 (50%)
Ductless mini split	*3 (100%)*	*7 (100%)*	*10 (100%)*
Yes	3 (100%)	7 (100%)	10 (100%)
No	--	--	--
Room air conditioner	*1 (100%)*	*5 (100%)*	*6 (100%)*
Yes	--	2 (40%)	2 (33%)
No	1 (100%)	3 (60%)	4 (67%)

As noted earlier, proper sizing of HVAC systems is important to ensure that systems operate efficiently and maximize occupant comfort and Manual J is the recognized method for calculating heating and cooling system sizes. Table 33 shows that most homes have oversized cooling equipment. Only eight percent of inspected 2012 IECC and stretch code homes comply with Manual J sizing criteria and in 68% of homes cooling capacity is more than double sized.

Table 33: Manual J Cooling Compliance

Cooling Capacity to Cooling Load Ratio	2012 IECC (n=47)	Stretch Code (n=46)	2012 IECC & Stretch Code (n=93)
Complies (≤ 115%)	1 (2%)	6 (13%)	7 (8%)
Fails (≤ 135%)	1 (2%)	2 (4%)	3 (3%)
Fails (≤ 230%, Manual J×2)	11 (23%)	9 (20%)	20 (22%)
Fails (>230%)	34 (72%)	29 (63%)	63 (68%)

4.3 Water Heating Equipment

There is no specific code requirement for water heater system efficiency, but there are federal standards. Current federal standards (effective for equipment manufactured on or after April 16, 2015) vary by type and size (at or below 55 gallons versus 55 gallons and above). See Appendix F for more detail. All water heaters in inspected homes met or exceeded federal standards in place when the equipment was manufactured.

The overall average Energy Factor of water heaters in combined 2012 IECC and stretch code baseline homes (EF 1.05) is higher than in the 2011 baseline study (EF 0.75). The current UDRH Energy Factor input for natural gas and propane conventional and instantaneous water heaters (EF 0.67) is lower than the average Energy Factor for combined natural gas and propane conventional and instantaneous water heaters observed in 2012 IECC and stretch code 2015 baseline homes (EF 0.77 unweighted and 0.75 weighted). The average Energy Factors for integrated fossil-fuel and heat pump water heaters in combined 2012 IECC and stretch code baseline homes are also higher than current UDRH inputs. The average Energy Factor for electric conventional storage tank water heaters in combined 2012 IECC and stretch code 2015 baseline homes (EF 0.90 unweighted and 0.89 weighted) is lower than the current UDRH input of EF 0.90.

Table 34 shows that most water heaters in inspected homes (71%) are natural gas or propane, 27% are electric, one is a tankless coil (oil) and one an indirect tank associated with a pellet boiler. Data point to more efficient water heaters replacing less inefficient water heaters in the new housing market. In the 2015 study, the percentages of natural gas and propane conventional standalone and indirect with tank water heaters are significantly lower than in the 2011 study while the percentages of natural gas and propane instantaneous water heaters and heat pump water heaters are significantly higher than in 2011.

Table 34: Water Heater Type by Code
(Base: All water heating systems)

Water Heater Type	2012 IECC (n=51)	Stretch Code (n=47)	2012 IECC & Stretch (n=98)
Storage, standalone (Natural Gas & {Propane)	20 (40%)	15 (32%)	35 (35%)
Instantaneous (Natural Gas & Propane)	14 (28%)	11(23%)	25 (25%)
Storage, standalone (Electric)	6 (12%)	8(17%)	14 (14%)
Heat pump Electric	7 (14%)	6 (13%)	13 (13%)
Indirect w/ storage tank (Natural Gas & Propane)	2 (4%)	5 (11%)	7 (7%)
Combi appliance (Propane)	1 (2%)	1 (2%)	2 (2%)
Indirect w/ storage tank (Pellet)	--	1 (2%)	1 (1%)
Tankless coil (Oil)	1 (3%)	--	1 (1%)

Table 35 shows the weighted and unweighted average Energy Factors for each type water heater in inspected 2012 IECC and stretch code homes. Heat pumps are by far the most efficient type of water heater, with an average energy factor of 2.69—no homes in previous baseline studies had a heat pump water heater.

Table 35: Water Heater Efficiency

Water Heater Energy Factors* 2012 IECC & Stretch Code Homes	Number of Water Heaters	Weighted Average EF	Unweighted Average EF
Conventional Standalone (Natural Gas & Propane)	35	0.64	0.65
Instantaneous Natural Gas & Propane**	27	0.91	0.91
Integrated (Natural Gas & Propane)	7	0.87	0.87
Conventional (Electric)	14	0.89	0.90
Heat Pump	13	2.66	2.69
Oil Boilers	1	85.3	85.3

*Does not include the tankless coil and the indirect heater from a pellet boiler.
**Includes combi appliances.

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Section 5 Ducts

This section presents high-level findings from 2012 IECC and stretch code homes for duct insulation and duct leakage. More detail on these measures can be found in Volume 2: Data Analysis Findings.

5.1 Duct Insulation

Most duct systems consist of a mix of metal ducts and flex ducts. The primary supply trunk is typically metal ductwork that has branches of flex duct which lead to individual registers. Flex ducts are always insulated with fiberglass insulation while metal ducts are insulated with either fiberglass insulation or bubble wrap insulation (the two types of insulation are pretty evenly split).

The average R-values of attic supply duct insulation (R-6.9 unweighted and weighted) and duct insulation on ducts installed in non-attic unconditioned space (R-6.0 unweighted and R 5.8 weighted) in combined 2012 IECC and stretch code 2015 baseline homes are significantly lower than in 2015 program homes (attic supply ducts R-7.9 and all other ducts R-6.5). Average unweighted duct insulation in combined 2012 IECC and stretch code 2015 baseline homes is higher than in the 2011 baseline study (attic supply duct insulation R-6.5 and average insulation in other unconditioned areas R-5.8) and higher than current UDRH inputs (attic supply ducts R-6.5 and ducts in all other unconditioned areas R-5.5.

Table 36 shows the average R-value of duct insulation for homes built under the 2012 IECC and stretch code.[13] Attic supply ducts are separated from all other ducts because they are subject to a higher code requirement (R-8 insulation) than other ducts in unconditioned space. As shown, stretch code homes have statistically significant lower attic supply duct insulation levels than homes built under the 2012 IECC.

[13] It is worth noting that 23 homes had at least some portion of attic ducts located under the attic insulation. These ducts are insulated by both the standard duct insulation as well as the attic insulation and therefore have higher performance.

Table 36: Average Home R-values for Duct Insulation

Attic Supply Duct Insulation	2012 IECC (n=29)	Stretch Code (n=31)	2012 IECC & Stretch Code (n=60)
Minimum	4.2	0	0
Maximum	9.0	9.2	9.2
Unweighted Average	7.1	6.6	6.9
Weighted Average	7.2[c]	6.3[c]	6.9
Median	8.0	6.5	7.2
Duct Insulation All Other Unconditioned Spaces	**2012 IECC (n=45)**	**Stretch Code (n=35)**	**2012 IECC & Stretch Code (n=80)**
Minimum	1.7	0	0
Maximum	9.4	10.1	10.1
Unweighted Average	6.1	6.0	6.0
Weighted Average	6.1	5.1	5.8
Median	6.1	6.4	6.2

[a] Statistically significant at the 90% confidence level

Table 37 shows that more than half of all homes do not satisfy the prescriptive code requirement (R-8) for attic supply duct insulation; these results vary by code, with stretch code homes showing the highest level of non-compliance (74% of homes below the prescriptive requirement). More than one-half of homes (71% of 2012 IECC homes and 69% of stretch code homes) do meet or exceed the duct insulation requirement of R-6 for all other ducts (not attic supply ducts) located in unconditioned space.

Table 37: Duct Insulation versus Prescriptive Code Requirements

Attic Supply Duct Insulation R-value	2012 IECC (n=29)	Stretch Code (n=31)
Less than R-8	14 (48%)	23 (74%)
Code R-8	10 (34%)	2 (7%)
More than R-8	5 (17%)	6 (19%)
All Other Unconditioned Space Duct R-value	**2012 IECC (n=45)**	**Stretch Code (n=35)**
Less than R-6	13 (29%)	11 (31%)
Code R-6	6 (13%)	3 (9%)
More than R-6	26 (58%)	21 (60%)

5.2 Duct Leakage

In addition to full inspections conducted at 50 2012 IECC homes, duct blaster tests were conducted at an additional 49 2012 IECC homes.

Both the 2012 IECC and stretch code have mandatory duct leakage requirements.

- The stretch code requirement is leakage to outdoors less than or equal to 8 CFM25 per 100 square feet of conditioned floor area or total leakage less than or equal to 12 CFM25 per 100 square feet of conditioned floor area.
- The 2012 IECC requirement is total leakage less than or equal to 4 CFM25 per 100 square feet of conditioned floor area.

Under both codes, duct tightness testing is not required if the air handler and all ducts are located within conditioned space.

Average duct leakage to the outside in combined 2012 IECC and stretch code 2015 baseline homes (3.9 CFM25/100 sq. ft. CFA unweighted and 3.8 weighted) is significantly lower than in 2011 baseline homes (12.4 CFM25/100 sq. ft. CFA unweighted and 11.9 CFM25/100 sq. ft. CFA weighted), but significantly higher than in 2015 program homes (2.6 CFM25/100 sq. ft. CFA). Average duct leakage to the outside in combined 2012 IECC and stretch code baseline homes is also lower than the current UDRH input of 11.9 CFM25/100 sq. ft. CFA. Most stretch code homes (93%) comply with the 2009 IECC code requirement of duct leakage to the outside less than or equal to 8 CFM25/100 sq. ft. CFA. There is no requirement for duct leakage to the outside in 2012 IECC.

Average total duct leakage in combined 2012 IECC and stretch code 2015 baseline homes (9.1 CFM25/100 sq. ft. CFA unweighted and weighted) is higher than the 2012 IECC requirement of **total** duct leakage less than or equal to 4; 21% of 2012 IECC baseline homes comply with this 2012 IECC requirement. There is no UDRH input for total duct leakage.

Table 38 shows that only three inspected 2012 IECC and stretch code homes have no ducts. Comparing 2012 IECC and stretch code homes, stretch code homes have a statistically significant higher percentage of homes with all ducts in conditioned space than 2012 IECC homes and a statistically significant lower percentage of homes with no ducts in conditioned space.

Table 38: Duct Location

Duct Location Unweighted Data	2012 IECC (n=99)	Stretch Code (n=46)	2012 IECC & Stretch Code (n=145)
All Ducts in Conditioned Space	8 (8%)[a]	9 (20%)[a]	17 (12%)
Some Ducts in Conditioned Space	36 (36%)	21 (46%)	57 (39%)
No Ducts in Conditioned Space	54 (55%)[a]	14 (30%)[a]	68 (47%)
No Ducts	1 (1%)	2 (4%)	3 (2%)

[a] Statistically significant at the 90% confidence level.

Table 39 shows statistics on duct leakage to the outside and Table 40 shows statistics on total duct leakage. There are no statistically significant differences in unweighted or weighted average leakage between 2012 IECC and stretch code homes. Average duct leakage in 2015 baseline homes is significantly lower than in 2011 baseline homes.

Unweighted average duct leakage to the outside dropped from 12.4 CFM25 per 100 square feet of conditioned floor area in the 2011 study to 3.9 CFM25 per 100 square feet of conditioned floor area in the 2015 study.

Table 39: Duct Leakage to the Outside

Leakage to Outside (LTO) CFM25/100 ft^2	2012 IECC (n=98) No Code Requirement	Stretch Code (n=43) Code is LTO ≤ 8 CFM25/100 ft^2	2012 IECC & Stretch (n=141)
Minimum (Best)	0.0	0.0	0.0
Maximum	20.2	28.7	28.7
Unweighted Average	3.9	4.1	3.9
Weighted Average	3.9	3.6	3.8
Median	3.0	2.8	3.0

Table 40: Total Duct Leakage

Unweighted Total Leakage CFM25/100 ft^2	2012 IECC (n=98) Code is Total Leakage ≤ 4 CFM25/100 ft^2	Stretch Code (n=42) Code is Total Leakage ≤ 12 CFM25/100 ft^2	2012 IECC & Stretch (n=140)
Minimum (Best)	0.0	0.0	0.0
Maximum	23.2	34.0	34.0
Unweighted Average	8.7	10.0	9.1
Weighted Average	9.0	9.4	9.1
Median	8.1	8.0	8.1

Table 41 shows compliance with mandatory duct leakage code requirements. As shown, overall, 43% of homes with ducts meet mandatory duct leakage code requirements and 57% do not. The 2012 IECC code requirements are harder to meet than the stretch code requirements so it is not surprising that a significantly higher percentage of stretch code homes (93%) comply with code requirements than 2012 IECC homes (21%).

Table 41: Duct Leakage Compliance with Code

Duct Leakage	2012 IECC (n=98) Code is Total Leakage ≤ 4 CFM25/100 ft^2	Stretch Code (n=43) Code is LTO ≤ 8 CFM25/100 ft^2	2012 IECC & Stretch Code (n=141)
Complies	21 (21%)[a]	40 (93%)[a]	61 (43%)
Fails	77 (79%)[a]	3 (7%)[a]	80 (57%)

[a] Statistically significant at the 90% confidence level.

6 Section 6 Air Infiltration

This section focuses on air infiltration in inspected 2012 IECC and stretch code homes. More detail on air infiltration results can be found in Volume 2: Data Analysis Findings.

In addition to full inspections at 50 2012 IECC homes, blower door tests were conducted at an additional 49 2012 IECC homes.

Average ACH50 in combined 2012 IECC and stretch code 2015 baseline homes (3.57 ACH50 unweighted and 3.52 weighted) is significantly lower than in 2011 baseline homes (4.48 ACH50 unweighted), but significantly higher than in 2015 program homes (2.9 ACH50). Average ACH50 in combined 2012 IECC and stretch code baseline homes is also lower than the current UDRH input of 4.48 ACH50. Most stretch code baseline homes (96%) comply with the 2009 IECC code requirement of less than or equal to seven ACH50, and 58% of 2012 IECC baseline homes comply with the 2012 IECC code requirement of less than or equal to three ACH50.

Like duct leakage, mandatory air infiltration code requirements are different under stretch code and 2012 IECC. The mandatory air infiltration code requirement changed from visual inspection or air infiltration testing of seven air changes per hour at 50 pascals (ACH50) or lower in the 2009 IECC and stretch code, to testing three ACH50 or lower in the 2012 IECC. Table 42 shows ACH50 statistics. There are no statistically significant differences in unweighted or weighted average air infiltration between 2012 IECC and stretch code homes.

Table 42: Air Infiltration

Air Infiltration ACH50	2012 IECC (n=98)	Stretch Code (n=46)	2012 IECC & Stretch (n=144)
Minimum (Best)	0.8	0.8	0.8
Maximum	6.6	8.4	8.4
Unweighted Average	3.50	3.72	3.57
Weighted Average	3.59	3.41	3.52
Median	3.3	3.5	3.3

Table 43 shows compliance with mandatory air infiltration requirements. As shown, overall, 70% of tested 2012 IECC and stretch code homes meet mandatory air infiltration code requirements and 30% do not. Given the code requirement for 2012 IECC homes is three or less ACH50 and the code requirement for stretch code homes is seven ACH50 or lower it is not surprising that 2012 IECC homes are significantly less likely to meet air infiltration code requirements, with 58% meeting code compared to 96% of stretch code homes.

Table 43: Air Infiltration Compliance with Code

Compliance with Mandatory Air Infiltration Requirements	2012 IECC (n=98) Code ≤ 3 ACH50	Stretch Code (n=46) Code ≤ 7 ACH50	2012 IECC & Stretch Code (n=144)
Complies	57 (58%)[a]	44 (96%)[a]	101 (70%)
Fails	41 (42%)[a]	2 (4%)[a]	43 (30%)

[a] Statistically significant at the 90% confidence level.

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Section 7 Lighting

This section focuses on lighting in inspected 2012 IECC and stretch code homes. More detail on lighting can be found in Volume 2: Data Analysis Findings.

Lighting data were collected at the fixture level for each home, with information about the type of bulbs installed, number of sockets in the fixture, whether the fixture was hard-wired or plug-load, and location of the fixture in the home. It is not always possible to make direct comparisons between lighting data from the 2011 baseline study with data from the 2015 baseline study because the 2011 study reported hard-wired fixture counts and the 2015 study reports socket counts as well and includes both plug load and hard-wired lighting. Across the full sample, only about nine percent of the total number of bulbs observed are plug-load, rather than hard-wired, bulbs.

The 2015 baseline shows a very clear increase in energy-efficient lighting—the weighted percentage of homes with10% or less of hard-wired fixtures containing energy-efficient bulbs fell from 65% in the 2011 study to seven percent in the 2015 study. (See Table 44) In the 2015 study almost one quarter of homes have energy-efficient bulbs in 75% to 100% of hard-wired fixtures.

Table 44: Weighted Percentage of Homes with Hard-Wired Fixtures Containing Energy-Efficient Bulbs

Percent of Fixtures with Energy-Efficient Bulbs in the Home	2012 IECC (n=50)	Stretch Code (n=45)	2012 IECC & Stretch Code (n=95)
10% or less	10%	13%	10%
11% to 30%	28%	26%	26%
30% to 49%	17%	16%	17%
50% to 74%	26%	9%	22%
75% to 100%	19%	35%	24%

However, less than one-half of inspected homes meet stretch code or 2012 IECC lighting requirements. The 2009 IECC and stretch code require that 50% or more of hard-wired fixtures contain energy-efficient bulbs. Table 45 shows that only 45% of inspected stretch code homes met this lighting requirement.

Table 45: Compliance with 2009 IECC and Stretch Code Lighting Requirement
(Results weighted to population)

Percent of Fixtures with Energy-Efficient Bulbs in the Home	Stretch Code (n=45)
Less than 50% of hard-wired fixtures with high efficacy bulbs	55%
50% or more hard-wired fixtures with high efficacy bulbs	45%

The hard-wired lighting fixture requirement for 2012 IECC is higher, requiring 75% or more of fixtures to contain energy-efficient bulbs. Table 46 shows that only 19% of inspected 2012 IECC homes met that requirement.

Table 46: Compliance with 2012 IECC Lighting Requirement
(Results weighted to population)

Percent of Fixtures with Energy-Efficient Bulbs in the Home	2012 IECC (n=50)
Less than 75% of hard-wired fixtures with high efficacy bulbs	81%
75% or more hard-wired fixtures with high efficacy bulbs	19%

Stretch code homes average about 78 fixtures (hard-wired and non-hard-wired) per home compared to about 68 per home for 2012 IECC homes. This likely reflects, in at least part, the statistically significant difference in the size of 2012 IECC and stretch code homes—the average stretch code home is 526 square feet larger than the average 2012 IECC home. However, as shown in Table 47, there are virtually no differences between 2012 IECC and stretch code homes in measured efficient bulb lighting fixture percentages.

Table 47: Types of Fixtures (All Types) In Homes

Weighted Number of Fixtures by Type of Bulb Installed in Homes	2012 IECC (n=50)	Stretch Code (n=45)	2012 IECC & Stretch Code (n=95)
Average number of total fixtures	67.9	77.7	71.2
% of fixtures containing CFL bulbs	17%	19%	18%
% of fixtures containing LED bulbs	31%	32%	31%
% of fixtures containing fluorescent tubes	3%	3%	3%
% of fixtures not containing energy-efficient bulbs	49%	47%	48%

8

Section 8 Appliances

This section focuses on appliances in inspected 2012 IECC and stretch code homes. Auditors collected data on refrigerators, dishwashers, ovens/ranges, clothes washers, dryers, and dehumidifiers. Findings related to refrigerators and clothes washers are summarized below. More detailed information, including information on dishwashers, ovens/ranges, dryers, and dehumidifiers can be found in Volume 2: Data Analysis Findings. See Appendix F for information on federal standards for appliances.

8.1 Refrigerators and Freezers

Every home had at least one refrigerator and most primary refrigerators (66%) were ENERGY STAR qualified when they were manufactured. This is down from 86% In the 2011 baseline. One likely factor in this decrease is that both refrigerator and freezer ENERGY STAR criteria and Federal Minimum Efficiency Standards changed in September 2014. The new ENERGY STAR criteria for refrigerators are ten percent less measured energy use than the minimum federal efficiency standards.[14]

Table 48 shows that most observed refrigerators (72%) were 23 cubic feet or larger and Table 49 shows that bottom freezer is the most common (67%) configuration. Although the bottom freezer configuration is most common in both 2012 IECC and stretch code homes, the percentage of bottom freezer refrigerators is significantly higher in 2012 IECC homes than stretch code homes.

Table 48: Primary Refrigerator Volume (ft^3)

Volume (ft^3)	2012 IECC (n=50)	Stretch Code (n=45)	2012 IECC & Stretch (n=95)
<16	--	1 (2%)	1 (1%)
16-19	2 (4%)	3 (7%)	5 (5%)
20-22	9 (18%)	11 (24%)	20 (21%)
23-25	14 (28%)	12 (27%)	26 (27%)
>25	25 (50%)	18 (40%)	43 (45%)

14 https://www.energystar.gov/products/appliances/refrigerators/key_product_criteria

Table 49: Primary Refrigerator Configuration

Type	2012 IECC (n=50)	Stretch Code (n=45)	2012 IECC & Stretch (n=95)
Bottom Freezer	38 (76%)[a]	26 (58%)[a]	64 (67%)
Side by Side	10 (20%)	15 (33%)	25 (26%)
Top Freezer	2 (4%)	2 (4%)	4 (4%)
Single Door	--	2 (4%)	2 (2%)

[a] Statistically significant at the 90% confidence level

8.2 Clothes Washers

Three homes did not have clothes washers, although the owner of one of those homes had plans to purchase one. One home had two clothes washers. Altogether, there were 93 clothes washers surveyed during on-site inspections of 2012 IECC and stretch code homes. ENERGY STAR certified clothes washers use about 25% less energy and 40% less water than regular washers. A large majority (86%) of clothes washers in 2012 IECC and stretch code homes were ENERGY STAR qualified. This is similar to the 2011 sample in which 80% of washers were ENERGY STAR qualified.

Table 50 shows the energy consumption in kWh/year of all the clothes washers for which such data were available. There is no statistically significant difference between 2012 IECC and stretch code homes. The weighted average consumption of clothes washers is 181.8 kWh/year.

Table 50: Clothes Washer kWh/Year

kWh/Year	2012 IECC (n=47)	Stretch Code (n=44)	2012 IECC & Stretch (n=91)
Minimum	85	85	85
Maximum	488	846	846
Unweighted Average	171.9	177.8	174.7
Weighted Average	174.6	194.8	181.8
Median	138	141	138

9 Section 9 Comparison to Program Homes

This section compares selected building characteristics in 2015 baseline study homes to the characteristics of single-family homes completed through the 2015 Program. Specifically, the baseline study homes considered in this comparison are homes that were built under the 2012 IECC and stretch code. The 2015 Program homes exclude those that failed to meet Program requirements. Comparisons address the following areas:

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

For conditioned/ambient walls, ceilings, and floors both R-values and U-values are addressed. U-values are the overall heat transfer coefficient for the entire wall, floor or ceiling assembly, not just the insulation. The lower the U-value is, the more energy efficient the assembly. U-values were calculated using REM/Rate software and 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.

There are no significant differences where baseline homes are more efficient than program homes. The following differences between 2015 baseline and Program homes are statistically significant at the 90% confidence level:

- The average U-value of conditioned/ambient walls is significantly lower (more energy efficient) in Program homes.
- The average U-value of flat ceilings is significantly lower (more energy efficient) in Program homes.
- The average R-value of vaulted ceilings is significantly higher in Program homes and the average U-value of vaulted ceilings is significantly lower (more energy efficient) in Program homes.
- The average R-value of foundation wall insulation in unconditioned basements is significantly higher in Program homes.
- The average R-value of attic supply duct insulation is significantly higher in Program homes.

- The average R-value of duct insulation on ducts installed in non-attic, unconditioned space is significantly higher in Program homes.
- Average duct leakage and air infiltration are significantly lower (better) in Program homes.
- Program homes have a significantly lower (better) average HERS score.

In Table 51, the first three columns of data are the unweighted averages of inspected 2012 IECC homes, inspected stretch code homes, and inspected 2012 IECC and stretch code homes combined. The fourth column is the average over all single-family homes that were completed through the 2015 Program—this excludes homes that failed to meet Program requirements. The fifth column is the current UDRH input; and the last column is the weighted average of inspected 2012 IECC and stretch code homes combined.

Table 51: Comparison of 2015 Baseline and 2015 Program Homes

Baseline Compared to 2015 Program Homes	2012 IECC	Stretch Code	2012 IECC & Stretch Code	MA 2015 Program	Current UDRH Input	Baseline Weighted 2012 IECC & Stretch Code
Average Conditioned/Ambient Wall Insulation R-value	20.7	20.9	20.8	21.1	n/a	21.0
Average Conditioned/Ambient Wall Insulation U-value	0.063	0.062	**0.062***	**0.060***	0.072	0.062
Average Flat Ceiling Insulation R-value	43.3	37.6	40.7	41.0	n/a	41.4
Average Flat Ceiling Insulation U-value	0.029	0.032	**0.030***	**0.027***	0.041	0.030
Average Vaulted Ceiling Insulation R-value	31.9	33.0	**32.4***	**37.6***	n/a	32.1
Average Vaulted Ceiling Insulation U-value	0.039	0.037	**0.038***	**0.031***	0.043	0.038
Average Conditioned/Basement Floor Insulation R-value	31.5	29.7	30.7	30.3	n/a	31.1
Average Conditioned/Basement Floor Insulation U-value	0.048	0.045	0.047	0.044	0.048	0.045
Foundation Wall Insulation - Conditioned Basements R-value	15.1	16.0	15.6	14.8	10.4	16.0
Foundation Wall Insulation - Unconditioned Basements R-value	1.1	0.4	**0.8***	**2.0***	3.1	1.1
Duct Insulation - Attic Supply R-value	7.1	6.6	**6.9***	**7.9***	6.5	6.9
Duct Insulation - All Other Unconditioned Spaces	6.1	6.0	**6.0***	**6.5***	5.5	5.8
Average Duct Leakage to Outside -- CFM25/100 sq. ft.	3.9	4.1	**3.9***	**2.6***	11.9	3.8
Air Infiltration—Average ACH50	3.5	3.7	**3.6***	**2.9***	4.48	3.5
Average HERS Score	69	66	**68***	**55***	n/a	67

*Significantly different at the 90% confidence level.

For the purposes of the summaries below, “baseline homes” refers to the combined 2012 IECC and stretch code data presented in Table 51.

Conditioned/Ambient Walls

The average R-value of insulation in conditioned/ambient walls is only slightly lower in 2015 baseline homes than in 2015 Program homes. Looking at U-values, the average U-value for 2015 baseline homes is significantly higher (less efficient) than for 2015 Program homes.

Ceilings-Flat Ceilings

The average R-value of flat ceiling insulation is lower and the average U-value higher (less energy efficient) in 2015 baseline homes than in 2015 Program homes; only the difference in U-values is statistically significant.

Ceilings-Vaulted Ceilings

The average R-value of vaulted ceiling insulation is significantly lower and the average U-value significantly higher (less energy efficient) in 2015 baseline homes than in 2015 Program homes.

Conditioned/Basement Floors

The average R-value of conditioned/basement floor insulation is higher in 2015 baseline homes than in 2015 Program homes, but not by much--the difference is not statistically significant. The average U-value of floor insulation is higher (less efficient) in baseline homes than program homes.

Foundation Walls

Average foundation wall R-value insulation levels in conditioned basements are higher in 2015 baseline homes than in 2015 program homes, but this difference is **not** statistically significant.

In contrast, the average R-value of foundation insulation in unconditioned basements is significantly lower in 2015 baseline homes than in 2015 program homes. Building code does not require these foundation walls to be insulated.

Duct Insulation

The average R-value of duct insulation on attic supply ducts is significantly lower in 2015 baseline homes than in 2015 Program homes. Average attic supply duct insulation levels in both 2015 baseline and 2015 Program homes fall short of the mandatory code requirement of R-8.

Average duct insulation levels for ducts in other unconditioned spaces are also lower in 2015 homes than in 2015 Program homes; this difference is statistically significant. The average R-values for both program and non-program homes exceed the mandatory code requirement of R-6.0 insulation in non-attic unconditioned spaces.

Duct Leakage and Air Infiltration

Both duct leakage and air infiltration are higher in 2015 baseline homes than in 2015 Program homes and the differences are statistically significant.

HERS Scores

Average HERS scores show a clear difference in the overall energy efficiency of 2015 baseline homes compared to 2015 Program homes. The average HERS score for 2015 Program homes of 55 is much lower (more energy efficient) than the unweighted average 68 HERS score or weighted average 67 HERS score for 2015 baseline homes: these differences are statistically significant.

10 Section 10 Comparison to Previous Baseline Studies

This section compares 2015 Baseline Study unweighted findings for the combined sample of 50 2012 IECC and 46 Stretch Code homes (built from 2013 through 2016) to previous baseline study findings. Most of the 2012 IECC and Stretch Code homes inspected in the 2015 study (91%) were built in 2015 (55%) or 2014 (36%). Tables addressing building shell measures (walls, ceilings, floors and windows), duct insulation, duct leakage and air infiltration show the mandatory or prescriptive code compliance path requirements in place during each study.

Before discussing how construction practices have changed from one study to another it is important to discuss the homes inspected in these studies. Wherever possible, 2015 Baseline Study findings are compared to four previous studies. The earliest is a 1999 study of Massachusetts and Rhode Island homes.[15] The second is a 2001 study prepared for the Massachusetts Board of Building Regulations and Standards (BBRS).[16] The third is the 2005 Baseline Study[17] submitted to the JMC (Joint Management Committee for the RNC program). The fourth is the 2011 Baseline Study which looked at homes built at the beginning of the 2009 IECC cycle.[18] The following descriptions of the homes inspected in the previous studies clearly show the sample homes were selected differently in each study. However, even though the samples of homes may not be directly comparable, there are enough years between the studies so that the comparisons show clear and reasonable trends in building characteristics and mechanical equipment efficiencies.

10.1 Previous Baseline Studies

1999 Baseline Study

- Seventy-five single-family homes constructed in 1996, 1997 and 1998
  - Fifty inspections conducted in 1998 on gas-heated homes in Boston Gas Company service territory
  - Twenty-five inspections conducted in 1999 in Massachusetts (16) and Rhode Island (9)—all types of heating systems

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[15] ENERGY STAR® Homes Program – Market Assessment and Baseline Study for Massachusetts and Rhode Island, Final Report, Prepared for The Joint Management Committee by the Delta Technologies Group, LLC, Marietta, Georgia. September 1999.

[16] Impact Analysis of the Massachusetts 1998 Residential Energy Code Revisions, Prepared for the Massachusetts Board of Building Regulations and Standards (BBRS) Boston, Massachusetts by XENERGY Inc., Portland, Oregon. May 14, 2001.

[17] Massachusetts ENERGY STAR® Homes: 2005 Baseline Study Part I: Inspection Data Analysis, Final Report, Prepared for The Joint Management Committee by Nexus Market Research and Dorothy Conant. May 2006.

[18] 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., The Cadmus Group, Inc. and Dorothy Conant. October 2012.

2001 BBRS Study

- Designed to reflect statewide building practices
- Random sample of 186 single- and two-family homes constructed in 1999 and 2000
- Homes selected geographically in proportion to 1999 building permits issued
- Two to seven homes in each of 30 towns
- Recruited homes through homeowners--percentage of custom homes likely higher than in the population of new homes in Massachusetts

2005 Baseline Study

- Inspected 144 non-ENERGY STAR single-family homes in 110 towns across the state
- Number of homes inspected in each area proportional to the number of single-family building permits issued in 2004
- All homes completed in 2004 or 2005
- Recruited homes through homeowners--percentage of custom homes (70%) is higher than in the population of new homes in Massachusetts

2011 Baseline Study

- Inspected 100 non-ENERGY STAR single-family homes in 74 towns across the state that were permitted in the beginning of the 2009 IECC cycle
- Number of homes inspected in each area proportional to the number of single-family building permits issued in 210
- All homes completed 2009 through 2011
- Recruited homes through homeowners—23% were custom homes

2015 Baseline Study

The comparisons presented in this section are based on raw data to be consistent with the how previous study data were presented. The percentage of custom homes in the sample is 26%.

10.2 Comparison Results

Table 52 shows that the average area of conditioned space in new homes increased each study year from 2,511 square feet in the 1999 study to 2,672 square feet in the 2005 study, but then dropped to 2,367 square feet in the 2011 study – the smallest average conditioned space area of all four previous studies. Average conditioned floor area increased to 2,816 square feet in the 2015 study, 22% higher than in the 2011 study. Table 52 also shows that unconditioned basements are the predominant foundation type in all five baseline studies.

Table 52: Conditioned Space and Basements

Conditioned Space and Basements	2015 Baseline	2011 Baseline	2005 Baseline	2001 BBRS	1999 Baseline
Average Area of Conditioned Space					
Number of Homes	96	100	144	186	75
Average Area sq. ft.	2,816	2,367	2,672	2,538	2,511
Type of Basement					
Number of Homes	96	100	144	186	
Unconditioned Basement	61%	78%	74%	86%	
Conditioned Basement	14%	12%	13%	7%	
More Than One Type*	20%	8%	9%	5%	
Slab on Grade	2%	1%	2%	2%	
Crawl Space	2%	1%	1%	0%	
No basement	1%	0%	1%	n/a	

* Homes with partial conditioned basements.

Table 53 shows a consistent trend of increasing insulation levels in conditioned/ambient walls. The average R-value increased from R-14.1 in the 1999 study to R-20.8 in the 2015 study. This change is consistent with a much higher percentage of 2015 homes having 2 x 6 framed walls and changes in building codes over the years requiring higher wall insulation levels. Average flat ceiling insulation levels changed little from the 1999 study to the 2005 study and then climbed from R-31.5 in the 2005 study to R-36.8 in the 2011 study and R-40.7 in the 2015 study. Likewise, average cathedral ceiling insulation levels climbed from R-31 in the 2005 study to R-35.5 in the 2011 study, but fell to R-32.1 in the 2015 study. Floor insulation R-values have increased in each study, from R-19.4 in the 1999 study to R-30.7 in the 2015 study.

Table 53: Walls, Ceilings and Floors

Walls, Ceilings and Floors	2015 Baseline	2011 Baseline	2005 Baseline	2001 BBRS	1999 Baseline
Relevant Prescriptive Path Code Requirements	2012 IECC, 2009 Stretch Code	2009 IECC	MA 6th Edition ***	MA 6th Edition ***	MA 6th Edition ***
Wall Insulation – Trends in Average R-Value					
Number of Homes	96	100	144	186	75
Average R-Value	20.8	19.4	16.3	14.1	14.1
Prescriptive Code Requirement	R-20 or R-13+5*	R-20 or R-13+5*	R-13 or R-19	R-13 or R-19	R-13 or R-19
Trends in Average R-Value by Framing Type					
2 x 4 Framing					
Number of Homes	1	7	58		52
Average R-value	18	14.5	12.7		11.9
2 x 6 Framing					
Number of Homes	94	93	82		23
Average R-value	20.6	19.7	19.1		19
Ceiling Insulation – Trends in R-Value*					
Flat Ceilings–Number of Homes	89	97	137	186	75
Average Flat Ceiling R-Value	40.7	36.8	31.5	31.5	30.5
Prescriptive Code Requirement	2012 IECC R-49 Stretch Code R-38	R-38	R-30 or R-38	R-30 or R-38	R-30 or R-38
Cathedral Ceilings–Number of Homes	60	65	65	24	n/a
Average Cathedral Ceiling R-Value	32.1	35.5	31	29.7	n/a
Prescriptive Code Requirement	2012 IECC R-49 Stretch Code R-38	R-38	R-30 or R-38	R-30 or R-38	R-30 or R-38
Floor Insulation over Unconditioned Basements – Trends in R-Value					
Number of Homes	79	85	117	183	61
Average R-value	30.7	26.7	18.5	18.6	19.4
Prescriptive Code Requirement	R-30**	R-30**	R-19 or R-25	R-19 or R-25	R-19 or R-25

*First value is cavity insulation, second is continuous insulation or insulated siding, so "13+5" means R-13 cavity insulation plus R-5 continuous insulation or insulated siding.
**Or insulation sufficient to fill the framing, in effect February 28, 1997
March 1, 2009 cavity. R-19 is minimum.
***The Massachusetts Sixth Edition code (in effect February 28, 1997 to March 1, 2009) has multiple prescriptive paths based on glazing percentage and heating degree days. The code values presented are the values in the prescriptive path table J5.2.1b.
Source: http://www.mass.gov/eopss/docs/dps/inf/780-cmr-6thed-residential.pdf

Table 54 shows that, over the years, windows in homes have consistently become more efficient. The average U-value improved from 0.41 in the 1999 study to 0.30 in the 2015 study.

Table 54: Windows

Windows	2015 Baseline	2011 Baseline	2005 Baseline	2001 BBRS	1999 Baseline
Relevant Prescriptive Codes	2012 IECC, 2009 Stretch Code	2009 IECC	MA 6th Edition	MA 6th Edition	MA 6th Edition
Window Efficiency – Trends in U-value					
Number of Homes	*96*	*100*	*144*	*75*	*186*
Average U-value	0.30	0.34	0.36	0.39	0.41
Prescriptive Code Requirement	2012 IECC 0.32 Stretch Code 0.35	0.35	.31 to .52	.31 to .52	31 to .52

Table 55 shows that, over the years, the percentage of homes with oil heating systems has fallen from 46% in the 2001 study to two percent in the 2015 study. At the same time, the percentage of homes with propane heating systems has grown from four percent in the 2001 study to 32% in 2015 and the percentage of natural gas heating systems has grown from 50% to 63%. The overall average AFUE of fossil fuel heating systems has increased from 85.6 in the 2001 study to 93.3 in the 2015 study.

Table 55: Space Heating

Space Heating	2015 Baseline	2011 Baseline	2005 Baseline	2001 BBRS	1999 Baseline
Space Heating Type and Fuel					
Number of Homes	*95**	*100*	*144*	*186*	
All Natural Gas Systems	63%	62%	47%	50%	
Natural Gas Furnace	56%	53%	28%	31%	
Natural Gas Hot Water Boiler	1%	6%	13%	16%	
Natural Gas Hydro-Air Boiler	6%	3%	6%	2%	
All Oil Systems	2%	13%	42%	46%	
Oil Furnace	1%	7%	2%	10%	
Oil Hydro –Air	1%	3%	13%	4%	
Oil Hot Water Boiler	0%	2%	27%	32%	
Oil Steam Boiler	0%	1%	0%	0%	
All Propane Systems	32%	21%	10%	4%	
Propane Furnace	28%	16%	3%	3%	
Propane Hydro-air	2%	4%	3%	0.5%	
Propane Hot Water Boiler	0%	1%	4%	0.5%	
Combi appliance	1%	0%	0%	0%	
Pellet Hot-Water Boiler	1%	1%	0%	0%	
Electric Resistance	0%	0%	1%	0%	
Electric GSHP	1%	3%	0%	0%	
Ducted Air Source Heat Pump	1%	0%	0%	0%	
Overall AFUE (Fossil Fuel Systems) **	93.3	90.9	86.0	85.6	

*Excludes one house where the primary heat source is a wood stove.

**The 96 homes in the 2015 study have 126 fossil fuel heating systems; the overall AFUE of fossil fuel systems is based on the 126 systems.

Table 56 shows that, consistent with heating systems, the percentage of homes with oil water heating systems decreased from 37% in the 2001 study to one percent in the 2015 study. The percentages of natural gas water heating systems have remained relatively stable over the years, ranging from 47% to 58%. In the 2015 study 52% of water heating systems were natural gas—the same percentage as in the 2001 study. While the percentage of oil water heating systems dropped, the percentage of propane water heating systems increased from four percent in the 2001 study to 20% in the 2015 study. Also, the percentage of electric water heaters grew sharply from seven percent of homes in the 2001 study to 27% in the 2015 study. With respect to the types of water heaters, the biggest changes over time are that homes inspected in 2015 were much more likely to have an electric water heater or a natural gas or propane instantaneous water heater, and less likely to have an indirect water heater integrated with a boiler.

Table 56: Water Heating Type and Fuel

Water Heating	2015 Baseline	2011 Baseline	2005 Baseline	2001 BBRS	1999 Baseline
Trends in Water Heating Fuel, Systems and Efficiency					
Water Heating Type and Fuel					
Number of Homes	*95**	*100*	*144*	*186*	
All Natural Gas Systems	52%	58%	47%	52%	
Nat. Gas – Conventional Storage	26%	44%	33%	42%	
Natural Gas – Integrated	6%	6%	14%	8%	
Natural Gas – Instantaneous	19%	8%	0%	0%	
Natural Gas – Tankless Coil	0%	0%	0%	2%	
All Oil Systems	1%	6%	41%	37%	
Oil – Conventional Storage	0%	0%	1%	5%	
Oil – Integrated	0%	6%	32%	13%	
Oil – Tankless Coil	1%	0%	8%	19%	
All Propane Systems	20%	16%	10%	4%	
Propane – Conventional Storage	10%	7%	3%	3%	
Propane – Integrated	1%	5%	6%	1%	
Propane – Instantaneous	8%	4%	1%	0%	
Electric	27%	20%	1%	7%	
Electric – Conventional Storage	14%	20%	1%	7%	
Electric – Heat Pump	13%	0%	0%	0%	

Table 57 shows Energy Factors are higher in the 2015 study than in the 2011 study for all but oil water heaters. Only one 2015 baseline home has an oil water heating system and it is an inefficient tankless coil system. The overall average Energy Factor has climbed from 0.59 in the 2001 study to 1.05 in the 2015 study; a large part of this increase reflects the increase in the penetration of electric heat pump water heaters (13% in the 2015 study), which have very high Energy Factors, and the increase in the penetration of efficient natural gas and propane instantaneous water heaters from one percent to 27%.

Table 57: Water Heating Energy Factors

Water Heating	2015 Baseline	2011 Baseline	2005 Baseline	2001 BBRS	1999 Baseline
Trends in Water Heating Fuel, Systems and Efficiency					
Water Heating Average Energy Factors					
Number of Water Heaters	*98*	*102*	*144*	*186*	
All Natural Gas Systems	0.78	0.69	0.64	0.59	
Nat. Gas – Conventional Storage	0.65	0.63	0.58	0.56	
Natural Gas – Integrated	0.87	0.84	0.78	0.77	
Natural Gas – Instantaneous	0.91	0.84	n/a	n/a	
Natural – Gas Tankless	n/a	n/a	n/a	0.48	
All Oil Systems	0.50	0.79	0.71	0.59	
Oil – Conventional Storage	n/a	n/a	0.61	0.59	
Oil – Integrated	n/a	0.79	0.78	0.76	
Oil – Tankless	0.50	n/a	0.44	0.48	
All Propane Systems	0.77	0.75	0.74	0.61	
Propane – Conventional Storage	0.65	0.64	0.63	0.54	
Propane – Integrated	0.88	0.85	0.79	0.8	
Propane – Instantaneous	0.91	0.83	0.79	n/a	
Electric – Conventional Storage	0.90	0.89	0.89	0.86	
Electric – Heat Pump	2.69	n/a	n/a	n/a	
Average Energy Factors (All Systems)	1.05	0.75	0.68	0.59	

*Two homes have two water heaters each. The average Energy Factors for the 2015 baseline study is based on the 98 systems observed in 2015.

Table 58 shows that the percentage of homes with central air conditioning has increased from study to study; from 56% in the 1999 study to 92% in the 2015 study. The average SEER increased to over 13.9 SEER in the 2015 study. This reflects an increase in the minimum federal efficiency standard to SEER 13 in early 2006. Average SEER values in all baseline studies are close to the minimum federal efficiency standard in place at the time of the study.

Table 58: Cooling Systems

Cooling Systems	2015 Baseline	2011 Baseline	2005 Baseline	2001 BBRS	1999 Baseline
Type of Air Conditioning Installed					
Number of Homes	96	100	144	186	75
Central Air Conditioning	92%	89%	63%	58%	56%
Window/Portable	3%	1%	21%	n/a*	n/a
Ductless Mini Splits	2%	0%	0%	0%	0%
No Air Conditioning	3%	10%	17%	n/a	n/a
Trends in Central Air Conditioning Efficiency and Size					
Number of Homes	90	87**	90	42	108
Average SEER	13.9*	13.6	10.6	10.2	10.2
Average Tons/Home	3.8**	4.0	5.2	n/a	4.5
Conditioned Space per Ton of Cooling					
Study	**2015 Baseline**	**2011 Baseline**	**2005 Baseline**	**2003 HERS Study[19]**	**2001 BBRS Study**
Number of Homes	90	87	90	35	108
Square Feet of Conditioned Space Per Ton of Cooling	727	638	618	816	604

*Includes central air conditioning, air source heat pumps and ductless mini splits.
**Includes only central air conditioning.

[19] A 2004 HERS rating study of non-ENERGY STAR-certified homes built in 2003. HERS Rating Analysis of Non-ENERGY STAR Homes in Massachusetts GDS Associates, Inc., May 2004.

Table 59 shows few homes now have ducts used only for air conditioning, only two percent in both the 2011 and 2015 studies. Additionally, the percentage of homes with no ducts located in unconditioned space being insulated has steadily declined from four percent in the 2001 study to 0% in the 2011 and 2015 studies. The average R-values of duct insulation changed little from the 2011 study to the 2015 study. Ducts located in attics have consistently been the most highly insulated across all study years, and duct wrap continues to be the insulation of choice among builders.

Table 59: Duct Insulation

Duct Insulation	2015 Baseline	2011 Baseline	2005 Baseline	2001 BBRS	1999 Baseline
Relevant Prescriptive Codes	2012 IECC, 2009 Stretch Code	2009 IECC	MA 6th Edition	MA 6th Edition	MA 6th Edition
Number of Homes	*93*	*100*	*144*	*186*	*75*
Percent of Air Cond. Homes with Boiler Heating System	2%	2%	16%	50%	24%
Number of Homes with Duct Systems in Uncond. Space	80	85	84	123	47
Percent of Homes Where All Ducts Insulated	87%	74%	67%	76%	83%
Percent of Homes Where Some Ducts Insulated	13%	26%	31%	20%	
Percent of Homes Where No Ducts Insulated	0%	0%	2%	4%	n/a
Overall Average R-Value of Duct Insulation	R-5.4	R-5.9	R-4.0	R-4.5	n/a
Average R-Value of Attic Duct Insulation	R-6.9*	R-6.4	R-4.6	R-4.7	n/a
Prescriptive Code Requirement	R-8	R-8	R-5	R-5	R-5
Average R-Value of Basement Duct Insulation	R-6.0**	R-5.6	R-3.5	R-4.4	n/a
Prescriptive Code Requirement	R-6	R-6	R-5	R-5	R-5
Most Common Type of Duct Insulation	Duct Wrap	Duct Wrap	Duct Wrap	Duct Wrap	Duct Wrap

*Unconditioned attic supply ducts.
**Non-attic ducts in unconditioned spaces.

Table 60 shows that average duct leakage dropped dramatically from the 2011 study to the 2015 study: average duct leakage to the outside dropped from 12.4 CFM25 per 100 square feet of conditioned floor area in the 2011 study to 3.9 CFM25 per 100 square feet of conditioned floor area in the 2015 study.

Air infiltration has consistently dropped over the years from 6.36 ACH50 in the 2005 study to 3.57 ACH50 in the 2015 study.

Table 60: Duct Leakage and Air Infiltration

Duct Leakage and Air Infiltration	2015 Baseline	2011 Baseline	2005 Baseline	2001 BBRS
Relevant Prescriptive Codes	2012 IECC, 2009 Stretch Code	2009 IECC	2003 IECC***	MEC 95***
Average Duct Leakage to the Outside (CFM25)				
Number of Homes with Ducts in Unconditioned Space	*124**	*69*	*89*	*22*
Duct Leakage to the Outside CFM25 per 100 Square Feet of Conditioned Space	3.9	12.4	21.7	n/a
Code Requirement	2012 IECC n/a Stretch ≤ 8	≤ 8	Ducts must be sealed using mastic with fibrous backing tape	
Air Infiltration – Trend Over Time				
Number of Homes	*146**	*100*	*144*	*184*
ACHnat	0.24	0.27	0.43	0.50
ACH50	3.57	4.78	6.36	n/a
Code Requirement	2012 IECC ≤ 3 Stretch Visual or ≤ 7	Visual or ≤ 7	Visual Inspection	

*Includes an additional 50 2015 baseline homes where only duct and air leakage testing was conducted.

Table 61 shows that, over the past ten years, there has been a dramatic increase in the proportion of energy-efficient lighting in homes from practically no energy-efficient bulbs in 2001 to less than one in twenty bulbs in 2005 to more than one in five in 2011 and 48% of bulbs in 2015. The average number of energy-efficient bulbs per home rose from close to zero in 2001 to close to two in 2005 to over nine fixtures with energy-efficient bulbs in 2011 and 47 energy-efficient bulbs in 2015. The ever-increasing saturation of energy-efficient lighting in recent years reflects better technologies, code requirements, customer acceptance of LED lighting, and falling prices.

Table 61: Lighting

Overall Lighting	2015 Baseline	2011 Baseline	2005 Baseline	2001 BBRS	1999 Baseline
Number of Homes	*95*	*99*	*144*	*186*	
Number of Bulbs*	9,291	4,506	5,973	7,394	
Percent Qualifying (energy efficient)	48%	20.2%	4.6%	0.1%	
Percent Not Qualifying	52%	79.8%	95.4%	99.9%	
Average Qualifying per home	47	9.2	1.9	<0.1	
Average Non-qualifying per home	51	36.3	40	40	

*The 2011 baseline study counted fixtures with energy-efficient bulbs rather than bulbs and the 2015 baseline counted sockets, including plug load sockets.

Appendix A 2012 and 2015 IECC Prescriptive Code Requirements

Table 62 presents the prescriptive code requirements associated with the 2012 and 2015 IECC code requirements.

Table 62: 2012 & 2015 IECC Insulation and Fenestration Requirements by Component[a]

Climate Zone	Fenestration U-Factor [b]	Skylight [b] U-Factor	Glazed Fenestration SHGC [b,e]	Ceiling R-value	Wood Frame Wall R-value	Mass Wall R-value [i]	Floor R-Value	Basement [c] Wall R-Value	Slab [d] R-Value & Depth	Crawl Space [c] Wall R-value
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.35	0.55	0.40	49	20 or 13+5[h]	8/13	19	10/13	10, 2 ft	10/13
5 and Marine 4	**0.32***	**0.55**	**NR**	**49**	**20 or 13+5[h]**	**13/17**	**30[g]**	**15/19**	**10, 2 ft**	**15/19**
7	0.32	0.55	NR	49	20+5 or 13+10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.32	0.55	NR	49	20+5 or 13+10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

a. R-values are minimums. U-factors and SHGC are maximums. When insulation is installed in a cavity which is less than the label or design thickness of the insulation, the installed R-value of the insulation shall not be less than the R-value specified in the table.
b. The fenestration U-factor column excludes skylights. The SHGC column applies to all glazed fenestration. Exception: Skylights may be excluded from glazed fenestration SHGC requirements in Climate Zones 1 through 3 where the SHGC for such skylights does not exceed 0.30.
c. "15/19" means R-15 continuous insulated sheathing on the interior or exterior of the home or R-19 cavity insulation at the interior of the basement wall. "15/19" shall be permitted to be met with R-13 cavity insulation on the interior of the basement wall plus R-5 continuous insulation on the interior or exterior of the home. "10/13" means R-10 continuous insulated sheathing on the interior or exterior of the home or R-13 cavity insulation at the interior of the basement wall.
d. R-5 shall be added to the required slab edge R-values for heated slabs. Insulation depth shall be the depth of the footing or 2 feet, whichever is less in Climate Zones 1 through 3 for heated slabs.
e. There are no SHGC requirements in the Marine zone.
f. Basement Wall Insulation is not required in warm-humid locations.
g. Or insulation sufficient to fill the framing cavity. R-19 is minimum.
h. First value is cavity insulation, second is continuous insulation or insulated siding, so "13+5" means R-13 cavity insulation plus R-5 continuous insulation or insulated siding. If structural sheathing covers 40 percent or less of the exterior, continuous insulation R-value shall be permitted to be reduced by no more than R-3 in the locations where structural sheathing is used-to maintain a consistent total sheathing thickness.
i. The second R-value applies when more than half the insulation is on the interior of the mass wall.

*Per most recent Massachusetts amendments (http://www.mass.gov/eopss/docs/dps/buildingcode/inf4/bbrs-780-cmr-chapter51-residential-aug16.pdf) the fenestration U-factor 2015 IECC prescriptive code requirement in Massachusetts is 0.30.

B Appendix B Federal Standards

This appendix shows federal standards[20] for:

- Refrigerators
- Room air conditioners
- Central air conditioners and heat pumps
- Water heaters
- Furnaces
- Boilers
- Dishwashers
- Clothes washers
- Clothes Dryers
- Faucets
- Showerheads
- Water closets
- Dehumidifiers

[20] Source: http://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8

B.1 REFRIGERATORS

The following standards apply to products manufactured starting on September 15, 2014:

Refrigerators	Equations for maximum energy use (kWh/yr)	
	Based on AV* (ft^3)	Based on av** (L)
1. Refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost	7.99AV + 225.0	0.282av + 225.0
1A. All-refrigerators—manual defrost	6.79AV + 193.6	0.240av + 193.6
2. Refrigerator-freezers—partial automatic defrost	7.99AV + 225.0	0.282av + 225.0
3. Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker	8.07AV + 233.7	0.285av + 233.7
3-BI. Built-in refrigerator-freezer—automatic defrost with top-mounted freezer without an automatic icemaker	9.15AV + 264.9	0.323av + 264.9
3I. Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service	8.07AV + 317.7	0.285av + 317.7
3I-BI. Built-in refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker without through-the-door ice service	9.15AV + 348.9	0.323av + 348.9
3A. All-refrigerators—automatic defrost	7.07AV + 201.6	0.250av + 201.6
3A-BI. Built-in All-refrigerators—automatic defrost	8.02AV + 228.5	0.283av + 228.5
4. Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker	8.51AV + 297.8	0.301av + 297.8
4-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker	10.22AV + 357.4	0.361av + 357.4
4I. Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service	8.51AV + 381.8	0.301av + 381.8
4I-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without through-the-door ice service	10.22AV + 441.4	0.361av + 441.4
5. Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	8.85AV + 317.0	0.312av + 317.0

Refrigerators	Equations for maximum energy use (kWh/yr)	
	Based on AV* (ft^3)	Based on av** (L)
5-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	9.40AV + 336.9	0.332av + 336.9
5I. Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service	8.85AV + 401.0	0.312av + 401.0
5I-BI. Built-In Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without through-the-door ice service	9.40AV + 420.9	0.332av + 420.9
5A. Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service	9.25AV + 475.4	0.327av + 475.4
5A-BI. Built-in refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service	9.83AV + 499.9	0.347av + 499.9
6. Refrigerator-freezers—automatic defrost with top-mounted freezer with through-the-door ice service	8.40AV + 385.4	0.297av + 385.4
7. Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service	8.54AV + 432.8	0.302av + 432.8
7-BI. Built-In Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service	10.25AV + 502.6	0.362av + 502.6
8. Upright freezers with manual defrost	5.57AV + 193.7	0.197av + 193.7
9. Upright freezers with automatic defrost without an automatic icemaker	8.62AV + 228.3	0.305av + 228.3
9I. Upright freezers with automatic defrost with an automatic icemaker	8.62AV + 312.3	0.305av + 312.3
9-BI. Built-In Upright freezers with automatic defrost without an automatic icemaker	9.86AV + 260.9	0.348av + 260.9
9I-BI. Built-in upright freezers with automatic defrost with an automatic icemaker	9.86AV + 344.9	0.348av + 344.9
10. Chest freezers and all other freezers except compact freezers	7.29AV + 107.8	0.257av + 107.8
10A. Chest freezers with automatic defrost	10.24AV + 148.1	0.362av + 148.1
11. Compact refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost	9.03AV + 252.3	0.319av + 252.3

Refrigerators	Equations for maximum energy use (kWh/yr)	
	Based on AV* (ft^3)	Based on av** (L)
11A.Compact all-refrigerators—manual defrost	7.84AV + 219.1	0.277av + 219.1
12. Compact refrigerator-freezers—partial automatic defrost	5.91AV + 335.8	0.209av + 335.8
13. Compact refrigerator-freezers—automatic defrost with top-mounted freezer	11.80AV + 339.2	0.417av + 339.2
13I. Compact refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic icemaker	11.80AV + 423.2	0.417av + 423.2
13A. Compact all-refrigerators—automatic defrost	9.17AV + 259.3	0.324av + 259.3
14. Compact refrigerator-freezers—automatic defrost with side-mounted freezer	6.82AV + 456.9	0.241av + 456.9
14I. Compact refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker	6.82AV + 540.9	0.241av + 540.9
15. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer	11.80AV + 339.2	0.417av + 339.2
15I. Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker	11.80AV + 423.2	0.417av + 423.2
16. Compact upright freezers with manual defrost	8.65AV + 225.7	0.306av + 225.7
17. Compact upright freezers with automatic defrost	10.17AV + 351.9	0.359av + 351.9
18. Compact chest freezers	9.25AV + 136.8	0.327av + 136.8

*AV = Total adjusted volume, expressed in ft^3, as determined in appendices A and B of subpart B of this part.
**av = Total adjusted volume, expressed in Liters.

B.2 Room Air Conditioners

Product class	Energy efficiency ratio, effective from Oct. 1, 2000 to May 31, 2014	Combined energy efficiency ratio, effective as of June 1, 2014

Product class	Energy efficiency ratio, effective from Oct. 1, 2000 to May 31, 2014	Combined energy efficiency ratio, effective as of June 1, 2014
1. Without reverse cycle, with louvered sides, and less than 6,000 Btu/h	9.7	11.0
2. Without reverse cycle, with louvered sides, and 6,000 to 7,999 Btu/h	9.7	11.0
3. Without reverse cycle, with louvered sides, and 8,000 to 13,999 Btu/h	9.8	10.9
4. Without reverse cycle, with louvered sides, and 14,000 to 19,999 Btu/h	9.7	10.7
5a. Without reverse cycle, with louvered sides, and 20,000 to 27,999 Btu/h	8.5	9.4
5b. Without reverse cycle, with louvered sides, and 28,000 Btu/h or more	8.5	9.0
6. Without reverse cycle, without louvered sides, and less than 6,000 Btu/h	9.0	10.0
7. Without reverse cycle, without louvered sides, and 6,000 to 7,999 Btu/h	9.0	10.0
8a. Without reverse cycle, without louvered sides, and 8,000 to 10,999 Btu/h	8.5	9.6
8b. Without reverse cycle, without louvered sides, and 11,000 to 13,999 Btu/h	8.5	9.5
9. Without reverse cycle, without louvered sides, and 14,000 to 19,999 Btu/h	8.5	9.3
10. Without reverse cycle, without louvered sides, and 20,000 Btu/h or more	8.5	9.4
11. With reverse cycle, with louvered sides, and less than 20,000 Btu/h	9.0	9.8
12. With reverse cycle, without louvered sides, and less than 14,000 Btu/h	8.5	9.3
13. With reverse cycle, with louvered sides, and 20,000 Btu/h or more	8.5	9.3
14. With reverse cycle, without louvered sides, and 14,000 Btu/h or more	8.0	8.7
15. Casement-Only	8.7	9.5

Product class	Energy efficiency ratio, effective from Oct. 1, 2000 to May 31, 2014	Combined energy efficiency ratio, effective as of June 1, 2014
16. Casement-Slider	9.5	10.4

B.3 Central Air Conditioners and Heat Pumps

Central air conditioners and central air conditioning heat pumps manufactured on or after January 23, 2006, and before January 1, 2015, shall have Seasonal Energy Efficiency Ratio and Heating Seasonal Performance Factor no less than:

Product class	Seasonal energy efficiency ratio (SEER)	Heating seasonal performance factor (HSPF)
(i) Split-system air conditioners	13	
(ii) Split-system heat pumps	13	7.7
(iii) Single-package air conditioners	13	
(iv) Single-package heat pumps	13	7.7
(v) Small-duct, high-velocity systems	13	7.7
(vi)(A) Space-constrained products—air conditioners	12	
(B) Space-constrained products—heat pumps	12	7.4

Each basic model of single-package central air conditioners and central air conditioning heat pumps and each individual combination of split-system central air conditioners and central air conditioning heat pumps manufactured on or after January 1, 2015, shall have a Seasonal Energy Efficiency Ratio and Heating Seasonal Performance Factor not less than:

Product class	Seasonal energy efficiency ratio (SEER)	Heating seasonal performance factor (HSPF)
(i) Split-system air conditioners	13	
(ii) Split-system heat pumps	14	8.2
(iii) Single-package air conditioners	14	
(iv) Single-package heat pumps	14	8.0
(v) Small-duct, high-velocity systems	12	7.2
(vi)(A) Space-constrained products—air conditioners	12	
(B) Space-constrained products—heat pumps	12	7.4

Each basic model of single-package central air conditioners and central air conditioning heat pumps and each individual combination of split-system central air conditioners and central air conditioning heat pumps manufactured on or after January 1, 2015, shall have an average off mode electrical power consumption not more than the following:

Product class	Average off mode power consumption $P_{W,OFF}$ (watts)
(i) Split-system air conditioners	30
(ii) Split-system heat pumps	33
(iii) Single-package air conditioners	30
(iv) Single-package heat pumps	33
(v) Small-duct, high-velocity systems	30
(vi) Space-constrained air conditioners	30
(vii) Space-constrained heat pumps	33

B.4 WATER HEATERS

The energy factor of water heaters shall not be less than the following for products manufactured on or after the indicated dates.

Product class	Storage volume	Energy factor as of January 20, 2004	Energy factor as of April 16, 2015
Gas-fired Storage Water Heater	≥20 gallons and ≤100 gallons	0.67−(0.0019 × Rated Storage Volume in gallons)	For tanks with a Rated Storage Volume at or below 55 gallons: EF = 0.675−(0.0015 × Rated Storage Volume in gallons). For tanks with a Rated Storage Volume above 55 gallons: EF = 0.8012−(0.00078 × Rated Storage Volume in gallons).
Oil-fired Storage Water Heater	≤50 gallons	0.59−(0.0019 × Rated Storage Volume in gallons)	EF = 0.68−(0.0019 × Rated Storage Volume in gallons).
Electric Storage Water Heater	≥20 gallons and ≤120 gallons	0.97−(0.00132 × Rated Storage Volume in gallons)	For tanks with a Rated Storage Volume at or below 55 gallons: EF = 0.960−(0.0003 × Rated Storage Volume in gallons). For tanks with a Rated Storage Volume above 55 gallons: EF = 2.057−(0.00113 × Rated Storage Volume in gallons).
Tabletop Water Heater	≥20 gallons and ≤120 gallons	0.93−(0.00132 × Rated Storage Volume in gallons)	EF = 0.93−(0.00132 × Rated Storage Volume in gallons).
Instantaneous Gas-fired Water Heater	<2 gallons	0.62−(0.0019 × Rated Storage Volume in gallons)	EF = 0.82−(0.0019 × Rated Storage Volume in gallons).
Instantaneous Electric Water Heater	<2 gallons	0.93−(0.00132 × Rated Storage Volume in gallons)	EF = 0.93−(0.00132 × Rated Storage Volume in gallons).

Note: The Rated Storage Volume equals the water storage capacity of a water heater, in gallons, as certified by the manufacturer.

Exclusions: The energy conservation standards shown in this paragraph do not apply to the following types of water heaters: Gas-fired, oil-fired, and electric water heaters at or above 2 gallons storage volume and below 20 gallons storage volume; gas-fired water heaters above 100 gallons storage volume; oil-fired water heaters above 50 gallons storage volume; electric water heaters above 120 gallons storage volume; gas-fired instantaneous water heaters at or below 50,000 Btu/h; and grid-enabled water heaters.

Grid-enabled water heaters. The energy factor of grid-enabled water heaters, as of April 30, 2015, shall not be less than 1.061−(0.00168 × Rated Storage Volume in gallons).

B.5 FURNACES

The AFUE of residential furnaces shall not be less than the following starting on the compliance date indicated in the table below:

Product class	AFUE (percent)[1]	Compliance date
(A) Non-weatherized gas furnaces (not including mobile home furnaces)	80	November 19, 2015.
(B) Mobile Home gas furnaces	80	November 19, 2015.
(C) Non-weatherized oil-fired furnaces (not including mobile home furnaces)	83	May 1, 2013.
(D4) Mobile Home oil-fired furnaces	75	September 1, 1990.
(E) Weatherized gas furnaces	81	January 1, 2015.
(F) Weatherized oil-fired furnaces	78	January 1, 1992.
(G) Electric furnaces	78	January 1, 1992.

Annual Fuel Utilization Efficiency, as determined in §430.23(n)(2) of this part.

Furnaces manufactured on or after May 1, 2013, shall have an electrical standby mode power consumption ($P_{W,SB}$) and electrical off mode power consumption ($P_{W,OFF}$) not more than the following:

Product class	Maximum standby mode electrical power consumption, $P_{W,SB}$ (watts)	Maximum off mode electrical power consumption, $P_{W,OFF}$ (watts)
(A) Non-weatherized oil-fired furnaces (including mobile home furnaces)	11	11
(B) Electric furnaces	10	10

B.6 Boilers

The AFUE of residential boilers, manufactured on or after September 1, 2012, and before January 15, 2021, shall not be less than the following and must comply with the design requirements as follows:

Product class	AFUE (percent)	Design requirements
(A) Gas-fired hot water boiler	82	Constant burning pilot not permitted. Automatic means for adjusting water temperature required (except for boilers equipped with tankless domestic water heating coils).
(B) Gas-fired steam boiler	80	Constant burning pilot not permitted.
(C) Oil-fired hot water boiler	84	Automatic means for adjusting temperature required (except for boilers equipped with tankless domestic water heating coils).
(D) Oil-fired steam boiler	82	None.

B.7 Dishwashers

The energy factor of dishwashers manufactured on or after May 14, 1994, must not be less than:

Product class	Energy factor (cycles/kWh)
(i) Compact Dishwasher (capacity less than eight place settings plus six serving pieces as specified in ANSI/AHAM DW-1 [Incorporated by reference, see §430.22] using the test load specified in section 2.7 of appendix C in subpart B)	0.62
(ii) Standard Dishwasher (capacity equal to or greater than eight place settings plus six serving pieces as specified in ANSI/AHAM DW-1 [Incorporated by Reference, see §430.22] using the test load specified in section 2.7 of appendix C in subpart B)	0.46

All dishwashers manufactured on or after May 30, 2013, shall meet the following standard—

(i) Standard size dishwashers shall not exceed 307 kwh/year and 5.0 gallons per cycle.

(ii) Compact size dishwashers shall not exceed 222 kwh/year and 3.5 gallons per cycle.

B.8 CLOTHES WASHERS

Clothes washers manufactured on or after March 7, 2015, and before January 1, 2018, shall have an Integrated Modified Energy Factor no less than, and an Integrated Water Factor no greater than:

Product class	Integrated modified energy factor (cu.ft./kWh/cycle)	Integrated water factor (gal/cycle/cu.ft.)
i. Top-loading, Compact (less than 1.6 ft^3 capacity)	0.86	14.4
ii. Top-loading, Standard (1.6 ft^3 or greater capacity)	1.29	8.4
iii. Front-loading, Compact (less than 1.6 ft^3 capacity)	1.13	8.3
iv. Front-loading, Standard (1.6 ft^3 or greater capacity)	1.84	4.7

B.9 CLOTHES DRYERS

Clothes dryers manufactured on or after January 1, 2015 shall have a combined energy factor no less than:

Product class	Combined energy factor (lbs/kWh)
i. Vented Electric, Standard (4.4 ft^3 or greater capacity)	3.73
ii. Vented Electric, Compact (120V) (less than 4.4 ft^3 capacity)	3.61
iii. Vented Electric, Compact (240V) (less than 4.4 ft^3 capacity)	3.27
iv. Vented Gas	3.30
v. Ventless Electric, Compact (240V) (less than 4.4 ft^3 capacity)	2.55
vi. Ventless Electric, Combination Washer-Dryer	2.08

B.10 FAUCETS

The maximum water use allowed for any of the following faucets manufactured after January 1, 1994, when measured at a flowing water pressure of 60 pounds per square inch (414 kilopascals), shall be as follows:

Faucet type	Maximum flow rate (gpm (L/min)) or (gal/cycle (L/cycle))
Lavatory faucets	2.2 gpm (8.3 L/min)[1 2]
Lavatory replacement aerators	2.2 gpm (8.3 L/min)
Kitchen faucets	2.2 gpm (8.3 L/min)
Kitchen replacement aerators	2.2 gpm (8.3 L/min)
Metering faucets	0.25 gal/cycle (0.95 L/cycle)[3 4]

NOTE:
[1]Sprayheads with independently-controlled orifices and manual controls.
The maximum flow rate of each orifice that manually turns on or off shall not exceed the maximum flow rate for a lavatory faucet.
[2]Sprayheads with collectively controlled orifices and manual controls.
The maximum flow rate of a sprayhead that manually turns on or off shall be the product of (a) the maximum flow rate for a lavatory faucet and (b) the number of component lavatories (rim space of the lavatory in inches (millimeters) divided by 20 inches (508 millimeters)).
[3]Sprayheads with independently controlled orifices and metered controls.
The maximum flow rate of each orifice that delivers a pre-set volume of water before gradually shutting itself off shall not exceed the maximum flow rate for a metering faucet.
[4]Sprayheads with collectively-controlled orifices and metered controls.
The maximum flow rate of a sprayhead that delivers a pre-set volume of water before gradually shutting itself off shall be the product of (a) the maximum flow rate for a metering faucet and (b) the number of component lavatories (rim space of the lavatory in inches (millimeters) divided by 20 inches (508 millimeters)).

B.11 Showerheads

The maximum water use allowed for any showerheads manufactured after January 1, 1994, shall be 2.5 gallons per minute (9.5 liters per minute) when measured at a flowing pressure of 80 pounds per square inch gage (552 kilopascals). When used as a component of any such showerhead, the flow-restricting insert shall be mechanically retained at the point of manufacture such that a force of 8.0 pounds force (36 Newtons) or more is required to remove the flow-restricting insert, except that this requirement shall not apply to showerheads for which removal of the flow-restricting insert would cause water to leak significantly from areas other than the spray face.

B.12 Water Closets

The maximum water use allowed in gallons per flush for any of the following water closets manufactured after January 1, 1994, shall be as follows:

Water closet type	Maximum flush rate (gpf (Lpf))
Gravity tank-type toilets	1.6 (6.0)
Flushometer tank toilets	1.6 (6.0)
Electromechanical hydraulic toilets	1.6 (6.0)
Blowout toilets	3.5 (13.2)

The maximum water use allowed for flushometer valve toilets, other than blowout toilets, manufactured after January 1, 1997, shall be 1.6 gallons per flush (6.0 liters per flush).

B.13 Dehumidifiers

Dehumidifiers manufactured on or after October 1, 2012 shall have an energy factor that meets or exceeds the following values:

Product capacity (pints/day)	Minimum energy factor (liters/kWh)
Up to 35.00	1.35
35.01-45.00	1.50
45.01-54.00	1.60
54.01-75.00	1.70
75.01 or more	2.5