2015-16 Massachusetts Single-Family Code Compliance/Baseline Study: Volume 4-FINAL REPORT

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Volume Number 4

CODE COMPLIANCE FINDINGS

SUBMITTED TO:
The Electric and Gas Program Administrators of Massachusetts

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ES Executive Summary

This report presents the results of the compliance aspect of the Massachusetts 2015-16 Single-Family Compliance/Baseline Study conducted by NMR Group, Inc., and Dorothy Conant ("the Team"). The compliance component of this study was designed to document compliance with the energy code for single-family homes built at the end of the 2009 International Energy Conservation Code (IECC) cycle, homes built at the beginning of the 2012 IECC cycle, and homes built under the stretch energy code. These results build on previous studies that documented compliance with homes built at the end of the 2006 IECC cycle and at the beginning of the 2009 IECC cycle. This executive summary presents the findings for each of these samples using the following code compliance methodologies:

- The code compliance checklist methodology developed by Pacific Northwest National Laboratory (PNNL), referred to as the PNNL approach
- An alternative methodology developed by NMR, the Massachusetts Program Administrators (PAs), and the Massachusetts Energy Efficiency Advisory Council (EEAC) Consultants, referred to as the MA-REC approach (Massachusetts Residential Evaluation Contract).

The MA-REC approach compares all homes to the IECC prescriptive requirements, regardless of the compliance path that was selected by the builder during construction. More details on these compliance methodologies can be found in Section 2.

Overall Compliance Findings

Figure 1 shows the statewide compliance findings for homes using the MA-REC approach. Findings are presented for homes that participated in the Residential New Construction (RNC) program and those that did not. In order to develop statewide compliance estimates the Team used single-family program penetration rates of 12% for homes built at the end of the 2006 IECC and the beginning of the 2009 IECC, 24% for homes built at the end of the 2009 IECC and the beginning of the 2012 IECC, and 77% for stretch code homes.[1] The penetration rate of homes in the 2015 RNC program is estimated to be 42% overall, up from 12% in the 2011 RNC program.

- As shown, compliance rose significantly over the course of the 2009 IECC cycle and then fell significantly at the beginning of the 2012 IECC cycle.
    - Compliance actually rose from the end of the 2006 IECC cycle to the beginning of the 2009 IECC cycle due to the inclusion of an air leakage requirement. This requirement is important and weighted accordingly under the MA-REC approach. Homes built under the beginning of the 2009 IECC cycle had very high compliance (99%) with the air leakage requirement,

[1] These penetration rates were calculated by comparing the single-family homes in the 2015 RNC program to 2013 permit activity for single-family new homes in Massachusetts.

which, combined with the importance of the measure, resulted in higher overall compliance scores.

- Stretch code homes show high compliance under this approach because they are compared to the 2009 IECC prescriptive requirements, which is the foundation of the stretch code.

Figure 1: Overall Compliance Findings Under the MA-REC Approaches

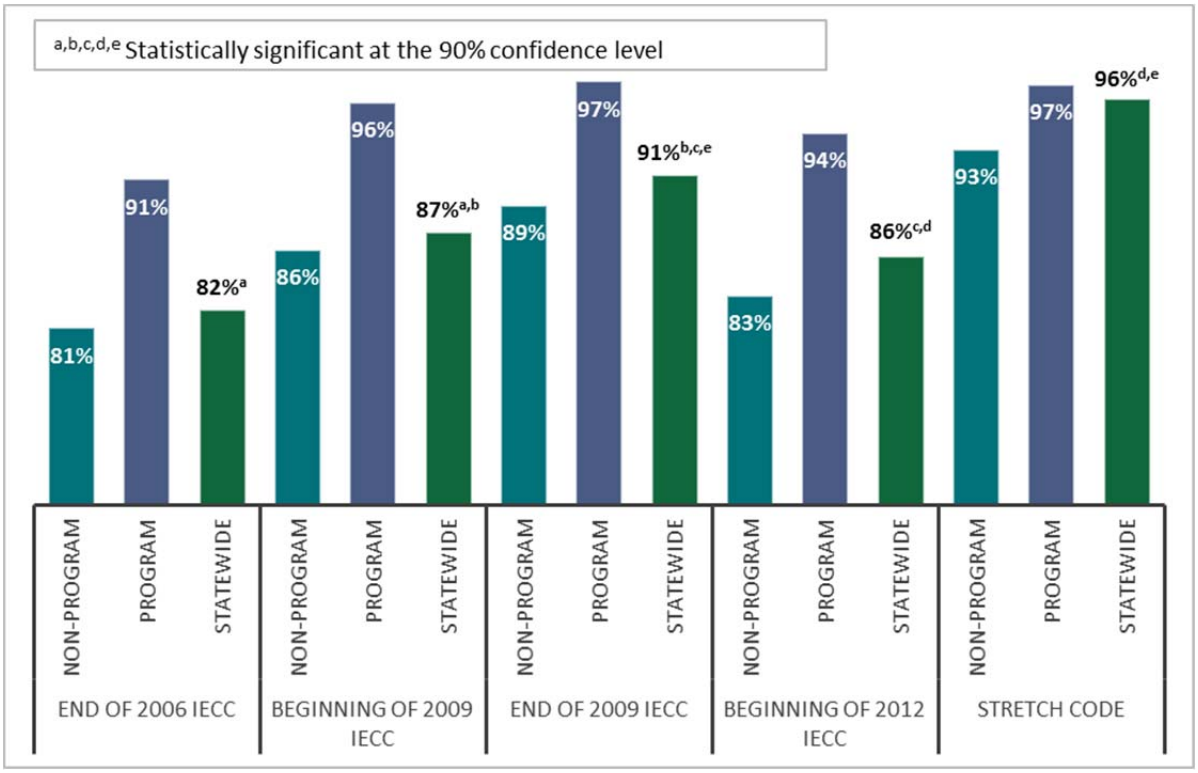


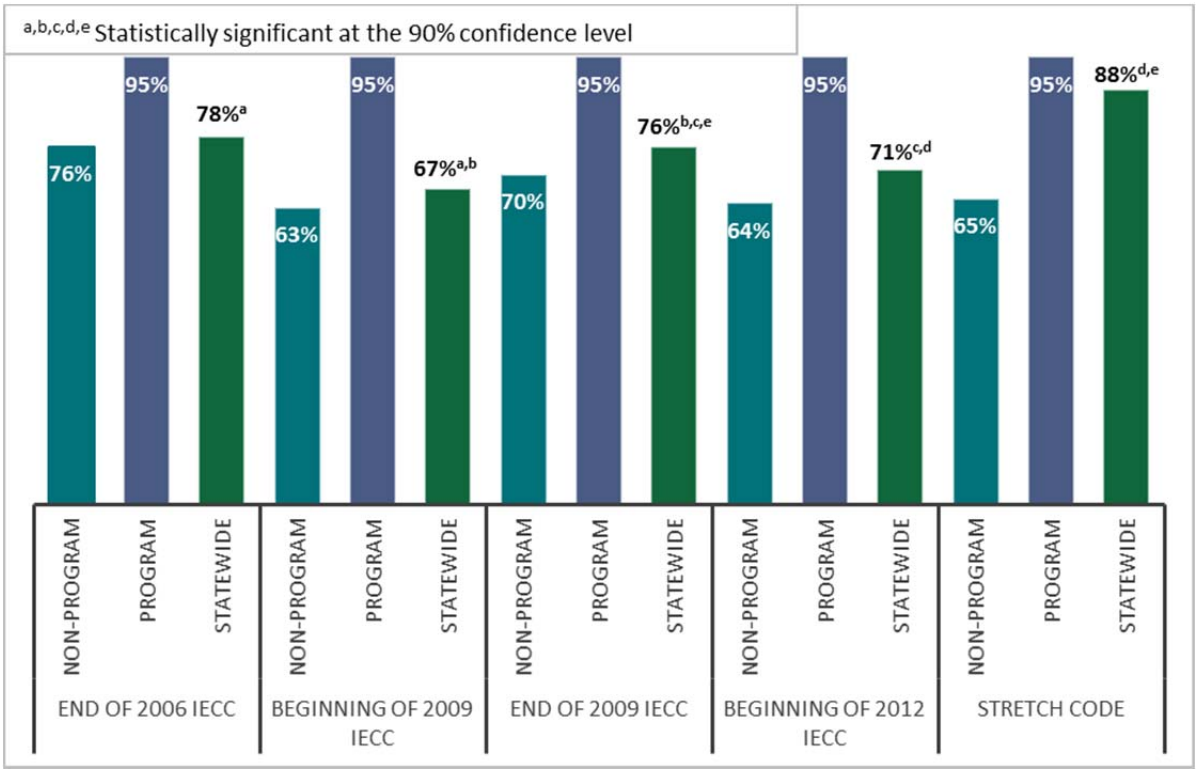
Figure 2 presents the overall statewide compliance findings under the PNNL approach. The Team assumed a compliance rate of 95% for program homes in this figure.[2] An additional assessment of statewide compliance rates with alternative program home compliance rates can be found in Section 3.2.1.

- The findings under the PNNL approach show significantly different compliance scores between the beginning and end of the code cycles. As shown in Figure 2, overall compliance dropped when the code switched from the 2006 IECC (78%) to the 2009 IECC (67%), then rose over the course of the 2009 IECC cycle (76% at the end of the 2009 IECC cycle), only to fall again upon implementation of the 2012 IECC (71%).

[2] Populating PNNL checklists is labor intensive. This factor, combined with the number of program homes considered in this assessment, prevented the Team from populating PNNL checklists for program homes. As a result, the Team assumed compliance rates for program homes under the PNNL approach in order to develop statewide compliance estimates.

- Stretch code[3] homes display high compliance (88%), though this is largely driven by the high penetration of stretch code homes in the RNC program (77%). Non-program stretch code homes had an average compliance score of 65% under this approach. The low compliance for non-program stretch code homes is due to the fact that 46% of these homes did not meet the HERS score requirements. On average, these homes had HERS scores that were 7 points higher than the code requirement.[4] That said, less than 1% of the stretch code homes that participated in the 2015 RNC program did not meet the HERS score requirements.

Figure 2: Overall Compliance Findings Under the PNNL Approach



MEASURE-LEVEL FINDINGS

This section details the statewide measure-level findings from the MA-REC approach. Details on the measure-level compliance of non-program and program homes can be found in Appendix C. Measure-level findings using the PNNL approach can be found in Section 3.2. The PNNL measure-level findings incorporate numerous checklist items, some of which are less influential on energy consumption or overall energy efficiency. As a result,

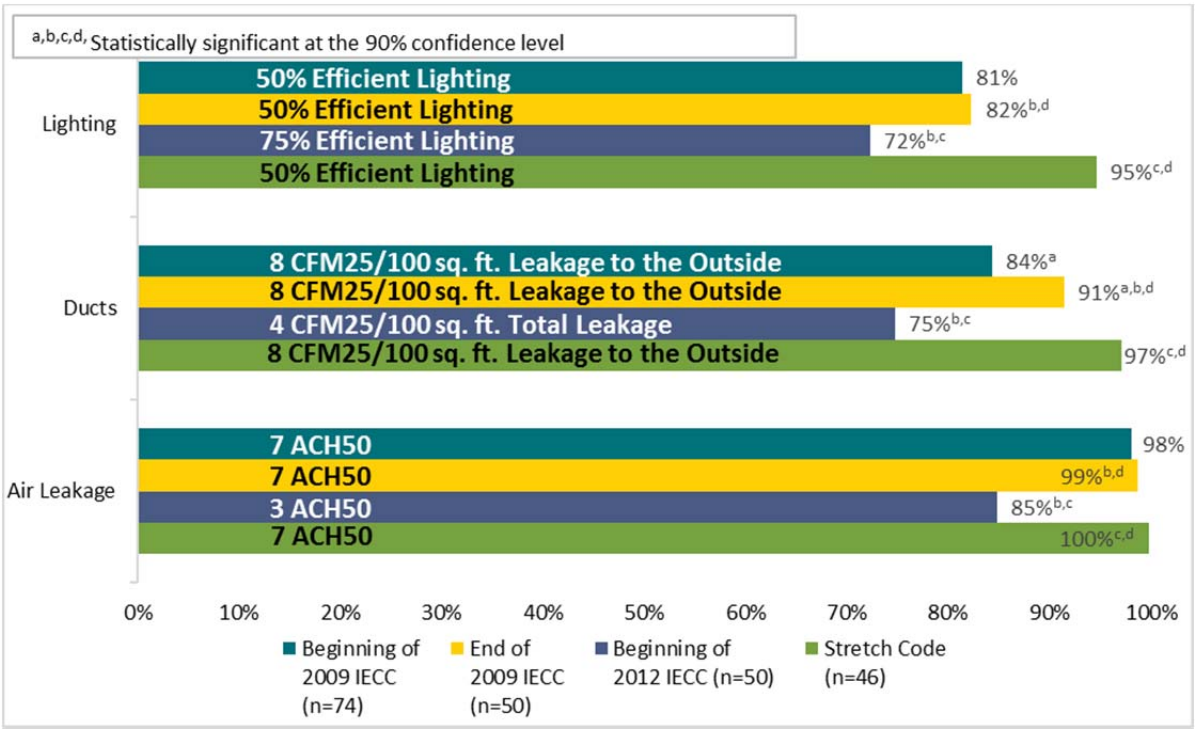
[3] The stretch code is a performance-based energy code which requires that homes comply with the mandatory requirements of the 2009 IECC and have a HERS score of 70 (for homes < 3,000 ft^2) or 65 (for homes ≥ 3,000 ft^2).
[4] The minimum difference between the code requirement and the actual HERS score was 1 point, while the maximum was 28 points.

the Team believes the MA-REC measure-level findings are more informative for assessing the effects of trainings provided under the Code Compliance Support Initiative (CCSI).

Figure 3 presents the statewide compliance findings for lighting, duct leakage and insulation, and air leakage for homes built under the 2009 IECC, the 2012 IECC, and the stretch code. The code requirements associated with each of these measures is listed in each bar of the chart.

- Each of these measures underwent a change in requirement from the 2009 IECC to the 2012 IECC (see Table 5). As shown, homes built at the beginning of the 2012 IECC cycle show significantly lower compliance than homes built at the end of the 2009 IECC cycle for each of these measures.

Figure 3: MA-REC Measure-Level Compliance—Lighting, Ducts, and Air Leakage*



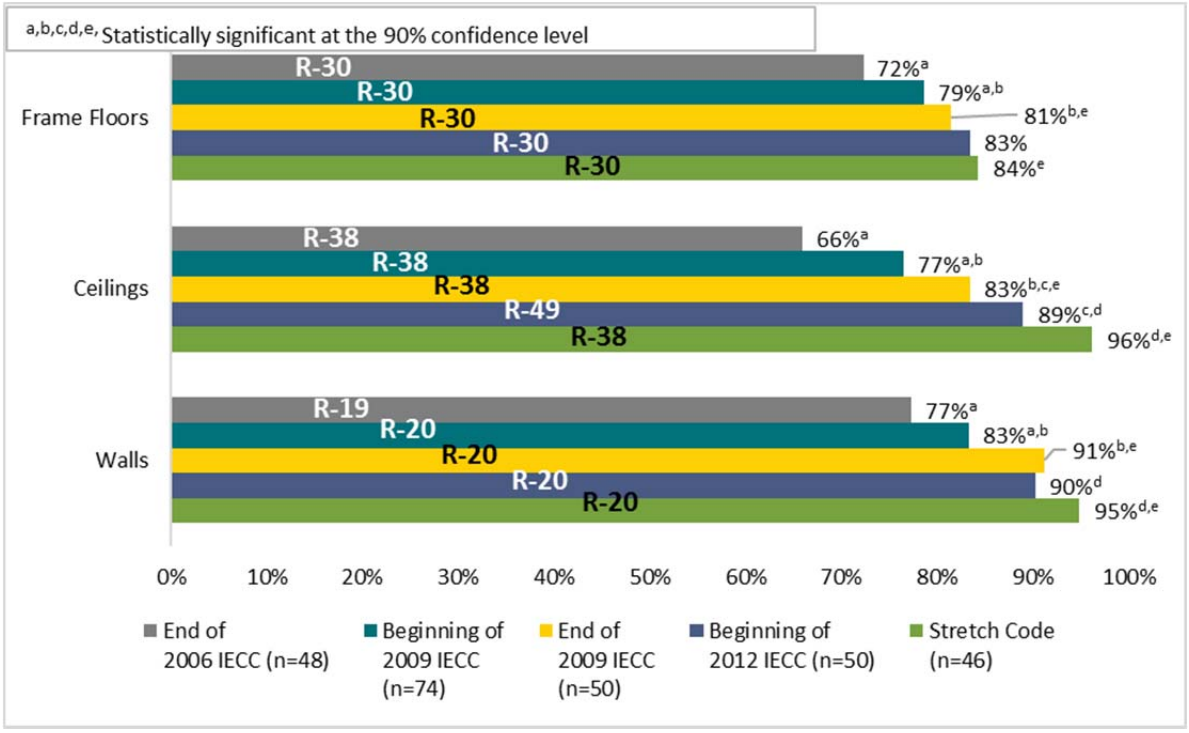
*Homes built at the end of the 2006 IECC cycle are excluded from this figure because the 2006 IECC did not have air leakage testing, duct leakage testing, or lighting requirements.

Figure 4 presents the compliance rates for frame floors, ceilings, and above-grade walls. Once again, the code requirements associated with each of these measures is listed in each bar of the chart. Each of these items assesses both the insulation level (R-value) and the insulation installation quality (installation grade).

- There has been a steady improvement in compliance over time for each of these code requirements in spite of some instances of increased code stringency.

  - The frame floor insulation requirement has remained the same over the course of each code change.
  - The ceiling insulation requirement remained the same between the 2006 and 2009 IECC cycles and then became more stringent with the adoption of the 2012 IECC.
  - The above-grade wall requirements changed from the 2006 IECC to the 2009 IECC, but remained the same when the code changed from the 2009 IECC to the 2012 IECC.
- While there has been a steady improvement in compliance with the frame floor insulation requirement, there is still an opportunity for compliance enhancement, particularly in non-stretch code homes.[5]
- Compliance with the wall insulation requirement increased significantly over the course of the 2009 IECC cycle.

Figure 4: MA-REC Measure-Level Compliance—Frame Floors, Ceilings, and Walls



Potential Savings from Compliance Enhancement

Table 1 and Table 2 present the gross technical potential savings from increasing non-compliant measures to the 2012 IECC and 2009 IECC (for stretch code homes) prescriptive

[5] Part of the opportunity with frame floors has to do with the insulation installation quality. The majority of frame floors are insulated with fiberglass batts that often sag in the framing cavity and lose contact with the subfloor. Improving the insulation installation quality of frame floor insulation would increase compliance with the code.

code levels in all homes (both program and non-program) built under the 2012 IECC and stretch code. In other words, these tables present the potential savings from achieving 100% compliance with the prescriptive requirements that are considered in the MA-REC approach. This assessment may overestimate the actual savings from 100% compliance for homes that use the trade-off or performance compliance paths. Under the trade-off and performance paths some measures are allowed to be non-compliant assuming a separate measure counteracts that by being over-compliant.

Table 1 presents the gross technical potential savings for homes built under the 2012 IECC. Savings are shown, by measure, for non-program homes, program homes, and statewide.[6] Each measure is listed as being either a mandatory requirement or a requirement that is subject to trade-offs in the UA trade-off or performance compliance paths. The total savings are shown two ways, with and without trade-offs; the total that accounts for trade-offs includes the impacts of above code practices on potential savings which reduces the overall savings potential. The savings for non-program homes are broken down by compliance path and then shown for the sample overall. As shown, homes utilizing the prescriptive and trade-off paths show higher savings potential than homes using the performance path. Air leakage, duct leakage, and lighting—all mandatory code requirements under the 2012 IECC—show the largest savings potential. Statewide, the potential savings from bringing all below-code measures to prescriptive code levels is 18%; this drops to 15% when the impact of measures that exceed the prescriptive code requirements are considered.

Table 1: Gross Technical Potential Savings for 2012 IECC Homes (% of Baseline MMBtu Consumption)

Building System	Requirement	2012 IECC Non-Program Homes				Program Homes	Statewide
		Pres.	Trade-Off	Perf.	Total		
Air Leakage	Mandatory	5%	5%	1%	4%	0%	3%
Duct Leakage	Mandatory	6%	5%	2%	4%	2%	4%
Lighting	Mandatory	5%	4%	4%	4%	0%	3%
Above Grade Walls	Path dependent	4%	2%	2%	2%	1%	2%
Windows	Path dependent	1%	1%	0%	1%	0%	1%
Ceiling	Path dependent	1%	3%	1%	2%	1%	1%
Frame Floors	Path dependent	2%	2%	2%	2%	1%	2%
Foundation Walls	Path dependent	3%	0%	2%	2%	1%	1%
Slabs	Path dependent	0%	0%	1%	0%	0%	0%
Total (No Trade-Offs)		26%	22%	14%	21%	6%	18%
Total (With Trade-Offs)		24%	20%	10%	19%	3%	15%

Table 2 shows the technical potential savings for stretch code homes. Once again, savings are presented for non-program homes, program homes, and statewide. None of the savings

[6] Program homes are likely to comply via the performance path since program participation requires a HERS rating. As a result, this could be an overstatement of potential savings from compliance enhancement for program homes.

are broken down by compliance path as the stretch code requires all homes to use a performance path for compliance. The statewide savings for stretch code homes are minimal (5% with no trade-offs and 0% with trade-offs). This is largely due to the fact that stretch code homes have such a high penetration (77%) in the RNC program. It should be noted that stretch code homes were compared to the 2009 IECC prescriptive requirements as that is currently the base code that the stretch code is built off of. The stretch code is set to be updated, based on the 2015 IECC, in January of 2017. This change will likely lead to an uptick in potential savings associated with stretch code homes. In particular, air leakage, duct leakage, and lighting, will have increased efficiency requirements with this change.[7]

Table 2: Gross Technical Potential Savings for Stretch Code Homes (% of Baseline MMBtu consumption)

Building System	Requirement	Non-Program Homes	Program Homes	Statewide
Air Leakage	Mandatory	0%	0%	0%
Duct Leakage	Mandatory	2%	0%	1%
Lighting	Path dependent*	3%	0%	1%
Above Grade Walls	Path dependent	1%	1%	1%
Windows	Path dependent	1%	0%	0%
Ceiling	Path dependent	1%	0%	0%
Frame Floors	Path dependent	1%	1%	1%
Foundation Walls	Path dependent	0%	1%	0%
Slabs	Path dependent	0%	0%	0%
Total (No Trade-Offs)		9%	4%	5%
Total (With Trade-Offs)		2%	0%	0%

*This is a path dependent requirement under the 2009 IECC but is a mandatory requirement under the 2015 IECC. The stretch code will soon be based upon 2015 IECC beginning January 2, 2017.

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 (expected in January of 2017). Note that other shell measures show potential as well, but these measures appear to present the highest level of opportunity for the PAs. Lighting currently appears to present a large compliance enhancement opportunity, but the Team feels 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

[7] A future study, conducted late in 2016 or early in 2017, will compare the sample of stretch code homes considered in this study to the 2015 IECC in order to identify the impact that the code change may have on stretch code home compliance and savings potential.

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.[8] 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, 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 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.

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

1 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 3 detailed evaluation work plan.[9] 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 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 4: Compliance Findings. In the next section, we explain the study objectives and research questions associated with the overall study. Please note that this particular report volume only addresses the compliance findings, while the baseline findings and UDRH information can be found in the other report volumes.

[9] 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.

1.2 STUDY OBJECTIVES AND BACKGROUND

This study was designed to meet the following two primary goals:

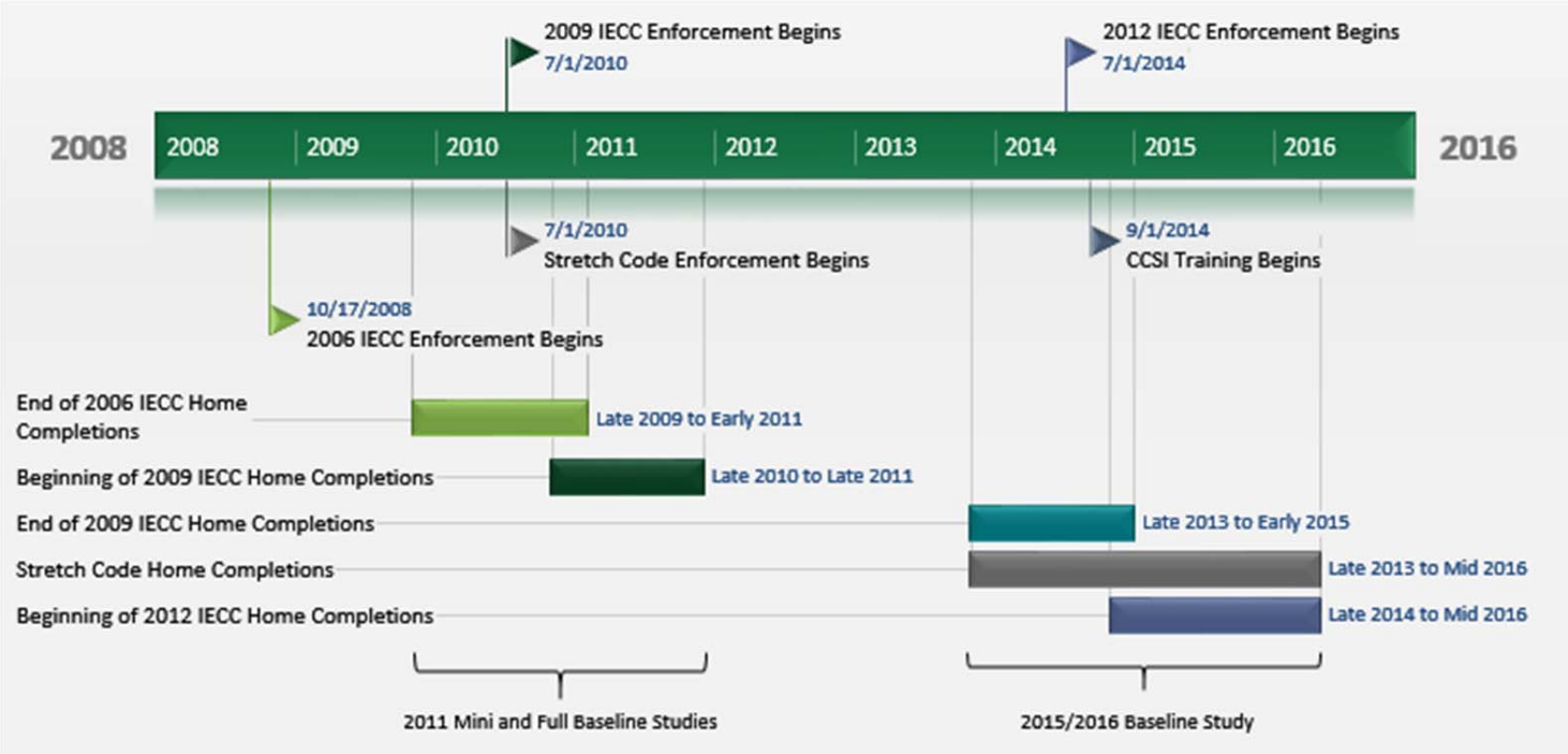
- To provide the PAs and EEAC Consultants with a code compliance assessment of newly constructed single-family homes permitted at the end of the 2009 International Energy Conservation Code (IECC) cycle, homes permitted during the beginning of the 2012 IECC cycle, and homes permitted under the stretch 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.[10] The inclusion of homes built at the end of the 2009 IECC cycle, the beginning of the 2012 IECC cycle, and 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 and the proportion of those savings that are attributable to the PAs' CCSI. Figure 5 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.

[10] 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 5: Timeline of Compliance Cycles and On-site Visit Home Completions



To leverage economies of scale, the Team, PAs, and EEAC 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.[11] The Team will work with the PAs and EEAC, 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[12] 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 TABLE FORMAT

Within each applicable table and figure in this report, the Team identified statistically significant results at the 90% confidence level using letters of the alphabet in superscript; in other words, there is a 90% probability that the compared results are truly different from each other, and only a 10% probability that observed differences happened by chance. In the example below (Table 3), a superscript *a* would indicate a statistically significant difference between the 2006 IECC and 2009 IECC, a superscript *b* would indicate a statistically significant difference between the 2009 IECC and 2012 IECC, and a superscript *c* would indicate a statistically significant difference between the 2012 IECC and stretch code.

[11] 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.

[12] U-factor*area. UA tradeoff allows a builder to trade off levels of insulation and glazing efficiency, for example.

Table 3: Example of Table Format

Measure	2006 IECC (n=XX)	2009 IECC (n=XX)	2012 IECC (n=XX)	Stretch Code (n=XX)
Variable 1	%[a]	%[a,b]	%[b,c]	%[c]

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

2 Section 2 Background and Methodology

This study builds on the aforementioned residential compliance work that was previously conducted in Massachusetts. The compliance results from the end of the 2006 IECC cycle and the beginning of the 2009 IECC cycle are included in this report so that they can be compared to the new findings to show a time-series of compliance results.

As part of this study, the Team used two separate methodologies to assess compliance with the various energy codes.

- The code compliance checklist methodology developed by Pacific Northwest National Laboratory (PNNL), referred to as the PNNL approach
- An alternative methodology developed by NMR, the Massachusetts PAs, and the Massachusetts EEAC Consultants, referred to as the MA-REC approach (Massachusetts Residential Evaluation Contract)

Please note that compliance with the prescriptive requirements is presented throughout Volume 2: Data Analysis Findings. Specifically, each applicable section of that report volume compares the current study samples to the appropriate prescriptive code requirements.

2.1 PNNL Methodology

PNNL developed a series of code compliance checklists as a way for states to consistently measure progress toward the American Recovery and Reinvestment Act (ARRA) requirement that states receiving federal funding should achieve 90% compliance with the 2009 IECC by 2017. The checklists score code compliance requirements on a point system; each measure is assigned a value of one, two, or three points based on its relative importance. Building-level checklist compliance is calculated as the total points for items marked compliant divided by total points for items marked either compliant or not compliant. This way, homes are not penalized if an item is not applicable or not observable.

There are two possibilities for determining statewide compliance with the checklist:

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

PNNL states a preference for the latter method, as it provides a finer level of detail for measuring the progress of a state toward reaching 90% compliance. This is the approach that has been adopted for this study. None of the homes included in this report complied with all applicable requirements and, as a result, the code compliance rate would be 0% for all samples if the requirement were 100% compliance with all applicable measures.

The checklist allows compliance to be assessed depending on which compliance approach the builder used: the prescriptive approach, the UA trade-off approach, or the performance approach. These compliance paths, as defined by the DOE,[13] are detailed below.

- **Prescriptive Path:** This is considered the simplest path. The requirements do not vary by building size, shape, window area, or other features. The 2006, 2009, and 2012 IECC have a single table of requirements for insulation R-values, window and door U-factors, and Solar Heat Gain Coefficient (SHGC). There is a corresponding U-factor table that permits compliance of less common component types (e.g., structural insulated panels), albeit without any cross-component trade-offs.[14] The 2009 and 2012 IECC also include a requirement for efficient lighting fixtures.[15]

- **UA Trade-off:** This is the path predominantly used by the RES*check*™ software. Based on the prescriptive U-factor table, it allows trade-offs whereby some envelope energy efficiency measures can fall below code requirements if balanced by other envelope measures that exceed code requirements.

- **Performance Path:**[16] This path allows compliance if the home has a calculated annual energy consumption (or energy cost) equal to or less than that of a standard reference design that just meets the code's prescriptive requirements. This path allows for crediting energy efficiency measures not accounted for in the other paths, such as renewable energy measures. The 2009 and 2012 IECC are augmented in Massachusetts by a state amendment that allows for performance-based code compliance by achieving a Home Energy Rating System (HERS) rater verified HERS rating of 75 or lower under the 2009 IECC and 65 or lower under the 2012 IECC.

The checklist is populated differently depending on the compliance approach the builder has selected. Under the prescriptive approach, applicable and observable items are simply marked as compliant or noncompliant. Under the trade-off or performance approaches, certain measures may be marked as compliant, even if they do not meet the prescriptive compliance levels identified in the checklist, if they are consistent with how the builder designed the building to comply. As the 2009 and 2012 IECC checklist instructions note, this is done assuming that "a valid worksheet or software report was submitted showing a compliant building."[17] The checklist is not a compliance path, but instead a means of assessing compliance. For example, if a home achieved compliance via the trade-off

[13] http://www.energycodes.gov/sites/default/files/documents/IECC2009_Residential_Nationwide_Analysis.pdf
[14] Under the prescriptive path, the U-factor table can be used as an alternative to the table summarizing R-value requirements. Note that this is not the same as the UA Trade-off approach, since using the U-factor table under the prescriptive path does not allow for trade-offs between building components.
[15] The lighting requirement also applies to the UA Trade-off approach in the 2009 IECC, but it does not apply to the performance path. It is a mandatory requirement under the 2012 IECC.
[16] The annual energy costs are only calculated for space heating, space cooling, and water heating end uses.
[17] The presence of this documentation was verified in jurisdictions where auditors physically visited the building department. In all other jurisdictions, building department documentation was verified via email or phone call.

approach, then the builder should have submitted a REScheck report to the building department indicating compliance with the energy code. In this case, the home may not meet the prescriptive requirements listed in the checklist, but it would be considered compliant for all shell measures because the REScheck documentation proves that the home complied via the trade-off approach.

2.2 MA-REC METHODOLOGY

The MA-REC approach uses energy modeling to develop a scoring system that is more calibrated to estimated energy consumption than is the PNNL approach. Unlike the PNNL approach, the MA-REC approach focuses only on code requirements that directly impact energy consumption. The methodology does not account for administrative or non-energy-related code requirements, and it does not consider the compliance path utilized by the builder. This methodology compares homes to the IECC prescriptive requirements that are applicable to each sample. As a result, the MA-REC approach does not account for trade-offs that may take place under the UA trade-off and performance paths for compliance. For this reason, it is possible that the MA-REC approach overstates the level of non-compliance and potential savings associated with homes that use the UA trade-off or performance paths for compliance. These paths allow for prescriptive non-compliance with certain measures assuming there are other measures that exceed the prescriptive requirements. The MA-REC approach does not attempt to address these complicating factors and this should be considered when reviewing the results associated with this methodology.

This approach utilizes REM/Rate™ energy consumption estimates to determine the relative importance of various code-related building components.[18] The consumption estimates of individual measures are compared to the overall estimated consumption for a sample of homes in order to develop a detailed point system that is calibrated to overall estimated energy consumption. The Team developed unique point systems for each code being considered as part of the study; this was done to account for the fact that codes vary in terms of what is required and what level of efficiency is required. Specifically, the sample of homes built under the 2006 IECC were used to develop the 2006 IECC point system, the 2009 IECC homes were used to develop the 2009 IECC point system, and the same approach was taken for the 2012 IECC and stretch code samples.[19]

The point system is developed on a ten-point scale where the most important measure (in terms of relative estimated energy consumption for the entire sample of homes) receives a total achievable score of ten points. Other measures are compared to the most important measure to develop a total achievable point value between zero and ten points. The following formula provides an example of how the total possible points for each measure is

[18] REM/Rate is an energy modeling tool that is used to develop Home Energy Rating Scores (HERS) and to support many residential new construction programs.
[19] Both samples from the 2009 IECC cycle (homes built at the beginning and end of the cycle) were used to develop the 2009 IECC point system.

developed (in this case assuming above-grade wall insulation was the most important measure in terms of relative consumption):

$$Points_{Possible} = \frac{(P_{TC} \times 10)}{AG_{TC}}$$

Where:

$$P_{TC} = Percentage\ of\ Total\ Consumption\ for\ Any\ Measure$$

$$AG_{TC} = Above - Grade\ Wall\ Pecentage\ of\ Total\ Consumption$$

The example below details how this calculation works for lighting in the 2009 IECC cycle.

$$Points\ Possible\ Lighting\ is\ 5.3 = \frac{(10\% \times 10)}{18\%}$$

Where:

$$P_{TC\ \text{Lighting}} = Percentage\ of\ Total\ Consumption\ for\ Lighting\ is\ 10\%$$

$$AG_{TC} = Above - Grade\ Wall\ Pecentage\ of\ Total\ Consumption\ is\ 18\%$$

Once the point system is developed, two models are used to calculate compliance for each home. One is an as-built model, or a model that represents the home as it actually exists, and the other is a code-built model that represents the same home built to meet prescriptive code requirements. The measure-level percentage change between the code-built models and as-built models is used to assign a point value to each of the measures included in this methodology. If the as-built model meets or exceeds the code for a given measure (less consumption), that measure is provided with the total possible points.[20] If the as-built model is less efficient than code, then the measure is provided with partial credit depending on the percentage change of the as-built consumption relative to the code-built consumption. The following formulas are used for these calculations:

$$PC_{Base} = \frac{(CB_{Cons} - AB_{Cons})}{AB_{Cons}}$$

Where:

$$PC_{Base} = Percentage\ difference\ between\ "code - built"\ and\ "as - built"\ models$$

$$AB_{Cons} = As - built\ consumption$$

$$CB_{Cons} = Code - built\ consumtpion$$

[20] By providing only the maximum possible points this method does not apply extra credit for exceeding the prescriptive code requirements.

Below is an example of how this step in the calculation would work for a home that does not meet the lighting code requirement from the 2009 IECC. In this scenario the as-built model has a higher consumption than the code-built model due to the fact that the code-built home is more efficient.

$$Percentage\ difference\ for\ Lighting\ (PC_{Base})\ is - 0.4\ = \frac{(3\ \text{MMBtu} - 5\ \text{MMBtu})}{5\ \text{MMBtu}}$$

Where:

$$AB_{Cons} = 5\ MMBtu\ for\ Lighting\ Consumption$$

$$CB_{Cons} = 3\ MMBtu\ for\ Lighting\ Consumption$$

The last step in the calculations is to convert the percentage difference in consumption between the models into an adjusted score for that component.

Where:

$$If\ PC_{Base} < 0\ then,$$

$$Points_{Scored}\ = 1 - |PC_{Base}| \times Points_{Possible}$$

$$If\ PC_{Base} > 0\ then\ Points_{Scored}\ = Points_{Possible}$$

Once again, this step is shown using the same lighting example from above. The first equation from above is used since the code-built model is more efficient than the as-built model. Had the as-built model been more efficient than the code-built model the home in this example would receive the full 5.3 points for lighting.

$$\text{Points Scored for Lighting is } 3.2 = 1 - |-0.4| \times 5.3$$

Where:

$$PC_{Base}\ for\ Lighting = -0.4$$

$$Points\ Possible\ Lighting = 5.3$$

Specifically, this methodology includes points and compliance calculations for the following building components:

- Roof insulation and installation quality
- Above-grade wall insulation and installation quality
- Foundation wall insulation and installation quality
- Window efficiency
- Frame floor insulation and installation quality
- Slab insulation and installation quality
- Air leakage
- Duct leakage and insulation
- Lighting efficiency

The number of points applied to individual components varies depending on the sample of homes and the code that is under consideration. For example, the distribution of points for the 2006 IECC compliance estimate differs from the 2009 IECC estimates primarily because certain measures (i.e., air infiltration and lighting efficiency) are not applicable to the 2006 IECC. The total possible points per measure varies between the samples because the relative impact of the measures shifts between different codes and also between different samples of homes; hence, it is critically important for the sample to represent the market. The relative number of possible points across the codes is not a critical comparison because the objective of this methodology is to compare compliance percentages (which are all compared on a 0% to 100% scale) across the codes; the total possible points simply provides an anchor with which to calculate the compliance percentages. This approach is similar to the PNNL scoring system, where the total possible points varies across different codes due to the number and importance of various code requirements. The PNNL method also re-scales everything on a 0% to 100% scale making compliance scores across codes comparable.

Table 4 presents the total possible points for each of the applicable building components within each sample of homes.

Table 4: Total Possible Points by Measure for Each Code Version

Measure	2006 IECC	2009 IECC	2012 IECC	Stretch Code
Lighting	n/a	5.3	6.1	5.6
Ceiling insulation and installation	4.4	6.1	4.8	4.2
Above-grade wall insulation and installation	10.0	10.0	10.0	8.5
Foundation wall insulation and installation	1.2	1.2	1.2	1.2
Window and skylight U-factor	9.3	9.0	9.8	10.0
Frame floor insulation and installation	3.2	4.6	4.3	2.9
Slab insulation and installation	0.3	0.5	0.8	0.6
Air leakage	n/a	9.3	7.8	8.0
Duct leakage and insulation	6.9	8.1	6.7	5.8
Total achievable points	35.4	54.0	51.6	46.8

2.3 Correlation of Methodologies to Overall Building Efficiency

The Team compared the compliance percentages for each methodology to the HERS scores for each of the code samples considered as part of this study. In all cases, the MA-REC approach showed a statistically significant correlation between the HERS score and overall code compliance at the 90% confidence level. The PNNL approach showed a similar relationship for some of the code groups, though the correlation was generally

weaker than it was under the MA-REC approach.[21] Please note that both code methodologies do not account for above-code building practices, which certainly influence the HERS score and overall efficiency of single-family homes.

Stretch code homes were the only code group that showed a stronger correlation between HERS scores and overall compliance under the PNNL approach as opposed to the MA-REC approach. This is due to the fact that, under the PNNL approach, the Team penalized stretch code homes that did not meet the core stretch code HERS score requirements (see Table 5). Given that the correlation analysis compared compliance percentages and HERS scores, this finding is not all that surprising.

2.4 Comparison of Key Code Requirements

To understand the code compliance results presented in this report, it is important to understand how key requirements vary by code. As shown in Table 5, the key differences between the 2006 IECC and the 2009 IECC are found in the wall insulation, air infiltration, duct leakage, duct insulation, and lighting requirements. The 2012 IECC has increased requirements over the 2009 IECC for ceiling insulation, fenestration U-factor, air infiltration, duct leakage, and lighting. As previously mentioned, the stretch code is a performance-based code that is founded on the 2009 IECC. Table 5 also provides details on the 2015 IECC, which is nearly identical to the 2012 IECC. Additional details on these code requirements, including updated stretch code requirements that will be enforced in January of 2017, can be found in Appendix A.

[21] The PNNL approach did not show a statistically significant correlation between HERS scores and overall compliance for the 2006 IECC and 2012 IECC code groups.

Table 5: Comparison of Key Requirements Across Codes*

Measure	2006 IECC requirement	2009 IECC requirement	2012 & 2015 IECC requirements	Stretch code requirement
Wall insulation	R-19 or R-13+5 (U-.060)	R-20 or R-13+5 (U-.057)	R-20 or R-13+5 (U-.057)	No requirement*
Ceiling insulation	R-38 (U-.030)	R-38 (U-.030)	R-49 (U-.026)	No requirement*
Floor R-value	R-30 (U-.033)	R-30 (U-.033)	R-30 (U-.033)	No requirement*
Foundation wall R-value	R-10/13 (U-.059)	R-10/13 (U-.059)	R-15/19 (U-.050)	No requirement*
Slab R-value	R-10, 2ft	R-10, 2ft	R-10, 2ft	No requirement*
Fenestration U-factor	U-0.35	U-0.35	U-0.32	No requirement*
Air infiltration	Requires air sealing, but there is no testing option. Compliance is assessed through visual inspection.	Requires air sealing. Compliance is assessed through visual inspection or air infiltration testing (7 ACH50)	Requires air sealing. Compliance is assessed via air infiltration testing (3 ACH50)	Requires air sealing. Compliance is assessed through visual inspection or air infiltration testing (7 ACH50)
Duct leakage	Requires duct sealing, but there is no testing option. Compliance is assessed through visual inspection.	Requires duct sealing, which is assessed through duct leakage testing (8 CFM25/100 ft^2 leakage to the outside)	Requires duct sealing, which is assessed through duct leakage testing (4 CFM25/100 ft2 of total leakage)**	Requires duct sealing, which is assessed through duct leakage testing (8 CFM25/100 ft^2 leakage to the outside)
Duct insulation	Supply and return ducts insulation to a minimum of R-8. Ducts in floor trusses shall be insulated to R-6.	Supply ducts in attics shall be insulated to a minimum of R-8. All other ducts shall be insulated to a minimum of R-6.	Supply ducts in attics shall be insulated to a minimum of R-8. All other ducts shall be insulated to a minimum of R-6.	No requirement*
Lighting	n/a	50% high efficacy lamps in permanently installed fixtures	75% high efficacy lamps in permanently installed fixtures	No requirement*

*The stretch code requires that homes comply with the mandatory requirements of the 2009 IECC and have a HERS score of 70 (for homes < 3,000 ft^2) or 65 (for homes ≥ 3,000 ft^2). These measures are not associated with mandatory requirements. The stretch code will be updated in January of 2017 and those requirements can be found in Appendix A.

**Both the 2012 IECC and 2015 IECC require mandatory duct leakage testing. The value of 4 CFM25/100 ft^2 of total leakage is a mandatory requirement under the 2012 IECC, but it is a prescriptive requirement under the 2015 IECC.

3 Section 3 Detailed Findings

This section presents detailed compliance findings for single-family homes built at the end of the 2006 IECC cycle, the beginning of the 2009 IECC cycle, the end of the 2009 IECC cycle, the beginning of the 2012 IECC cycle, and homes built under the stretch code.[22] Results are presented for program homes, non-program homes, and statewide using both the PNNL and MA-REC methodologies. The MA-REC section highlights statewide findings, while the PNNL approach focuses on the details associated with non-program homes. The Team did not run RNC program homes through the PNNL checklist and as a result the statewide estimate for this approach is somewhat limited (see Section 3.2.1).

The following list identifies the key findings that are presented throughout this section of the report.

- ***Air leakage, duct leakage, and lighting—all mandatory requirements under the 2012 IECC—show the most savings potential from compliance enhancement in non-stretch code homes (Table 6).***
- ***Stretch code homes display limited savings potential when compared to the 2009 IECC prescriptive requirements (Table 7). The limited savings are, in part, due to the high RNC program penetration rate for stretch code homes (77%). The stretch code will be updated in January of 2017 and that will likely result in decreased compliance (and an increase in potential for compliance enhancement with stretch code homes).***
- ***Using the PNNL approach, non-program compliance rates are significantly higher at the end of the code cycles (76% at the end of the 2006 IECC cycle and 70% at the end of the 2009 IECC cycle) than they are at the beginning of the code cycles (63% at the beginning of the 2009 IECC cycle and 64% at the beginning of the 2012 IECC) (Figure 10).[23]***
- ***Using the MA-REC approach, statewide compliance is significantly higher at the end of the 2009 IECC cycle (91%) than at the beginning of the 2009 IECC (87%) or 2012 IECC cycle (86%) (Figure 6).***
- ***Using the PNNL approach, non-program compliance is substantially higher using the UA trade-off and performance paths than it is using the prescriptive approach (Figure 10).***
- ***Compliance with the 2009 IECC and 2012 IECC lighting requirements is low (relative to other measures) under both the PNNL and MA-REC approaches (Table 8 and Figure 7).***

[22] The findings from homes built at the end of the 2006 IECC cycle and the beginning of the 2009 IECC cycle are from the 2011 baseline study on-site inspections.
[23] Statewide compliance rates using the PNNL approach are presented in Table 9.

- ***Lighting, duct leakage, and air leakage requirements all underwent a change between the 2009 IECC and 2012 IECC. These requirements clearly had an effect on compliance because homes built at the beginning of the 2012 IECC cycle have significantly lower compliance scores (under the MA-REC approach) for these measures than do homes that were built at the end of the 2009 IECC cycle (Figure 7).***
- ***The high compliance for stretch code homes under the MA-REC approach is due to the fact that stretch code homes are currently based on the 2009 IECC and, when compared to those prescriptive requirements, offer fewer savings opportunities from compliance enhancement than non-stretch code homes (Figure 6).***

3.1 MA-REC APPROACH FINDINGS

As previously noted, this methodology compares homes to the IECC prescriptive requirements that are applicable to each sample. As a result, the MA-REC approach does not account for trade-offs that may take place under the UA trade-off and performance paths for compliance. For this reason, it is possible that the MA-REC approach overstates the level of non-compliance and potential savings associated with homes that use the UA trade-off or performance paths for compliance. These paths allow for prescriptive non-compliance with certain measures assuming there are other measures that exceed the prescriptive requirements.

Figure 6 shows the statewide compliance levels for each of the samples considered in this study. The Team conducted an assessment of compliance for single-family homes that participated in the RNC program in order to develop a statewide compliance estimate that captures all single-family homes. While the PNNL statewide compliance estimates assume compliance scores for program homes (see Section 3.2.1), the Team actually measured program home compliance under the MA-REC approach. Using program REM/Rate files from 2011 and 2015 the Team was able to calculate single-family program compliance scores for each of the compliance samples included in this study. As is the case using the PNNL approach, the Team used single-family program penetration rates of 12% for homes built at the end of the 2006 IECC and the beginning of the 2009 IECC, 24% for homes built at the end of the 2009 IECC and the beginning of 2012 IECC, and 77% for stretch code homes.[24] Including program homes increases overall compliance estimates from one to three percent under the MA-REC approach when compared to the non-program compliance scores.

Compliance rates are significantly higher at the end of the 2009 IECC cycle than at the beginning of the 2009 IECC or 2012 IECC cycles.[25] This increase may be partially due to

[24] These penetration rates were calculated by comparing the single-family homes in the 2015 RNC program to 2013 permit activity for single-family new homes in Massachusetts.

[25] The increase in code compliance from the end of the 2006 IECC to the beginning of the 2009 IECC appears to be driven by the inclusion of the air leakage requirement in the 2009 IECC. Compliance with the air leakage

the fact that market actors become increasingly aware of code requirements and adapt to them over the course of a code cycle. Homes built under the stretch code show the highest compliance percentage (96%) of any group; compliance with the stretch code is significantly higher than it is for homes built at the end of the 2009 IECC cycle (91%) and homes built at the beginning of the 2012 IECC cycle (86%). Note that stretch code homes were compared to the 2009 IECC prescriptive requirements under the MA-REC approach; had they been compared to the 2012 IECC, the overall compliance score would be lower.[26]

Figure 6: Compliance Rates by Code Group Using the MA-REC Approach

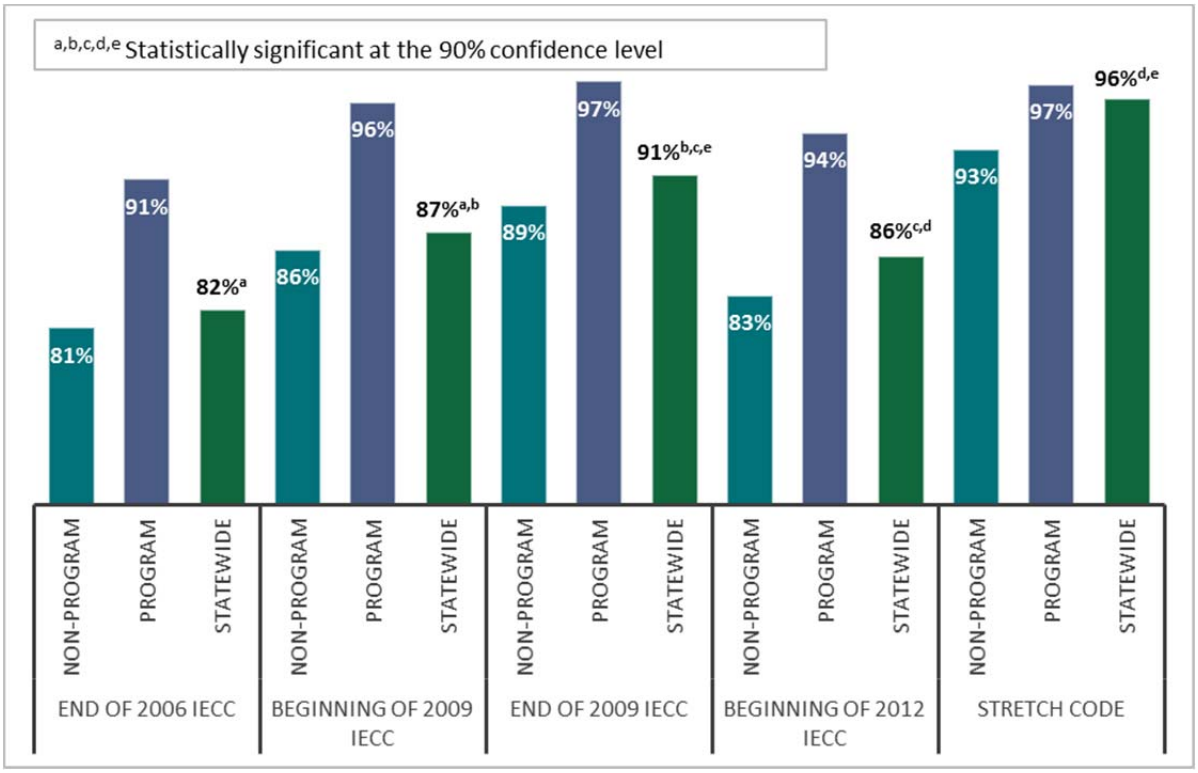


Figure 7 through Figure 9 present statewide measure-level compliance findings using the MA-REC approach. More detail on the measure-level compliance of non-program and program homes can be found in Appendix C. **It is important to keep in mind that these compliance scores do not represent the proportion of homes that comply with the code. These compliance scores represent the percent change in estimated energy consumption between as-built and code-built energy models.** For example, if a home had an as-built lighting consumption of 10 MMBtu/yr, and the same home built to the prescriptive code requirements (code-built) had lighting consumption of 8 MMBtu/yr, then

requirement, which is a high impact measure, was very high at the beginning of the 2009 IECC cycle and helped drive compliance upward for that sample of homes.

[26] The stretch code is actually more stringent than the 2009 IECC, as it requires a HERS score of 65 or 70 depending on the size of the home. Unfortunately, it is not possible to account for the HERS requirement under the MA-REC approach. As a result, stretch code homes were simply compared to the 2009 IECC prescriptive requirements for compliance calculations.

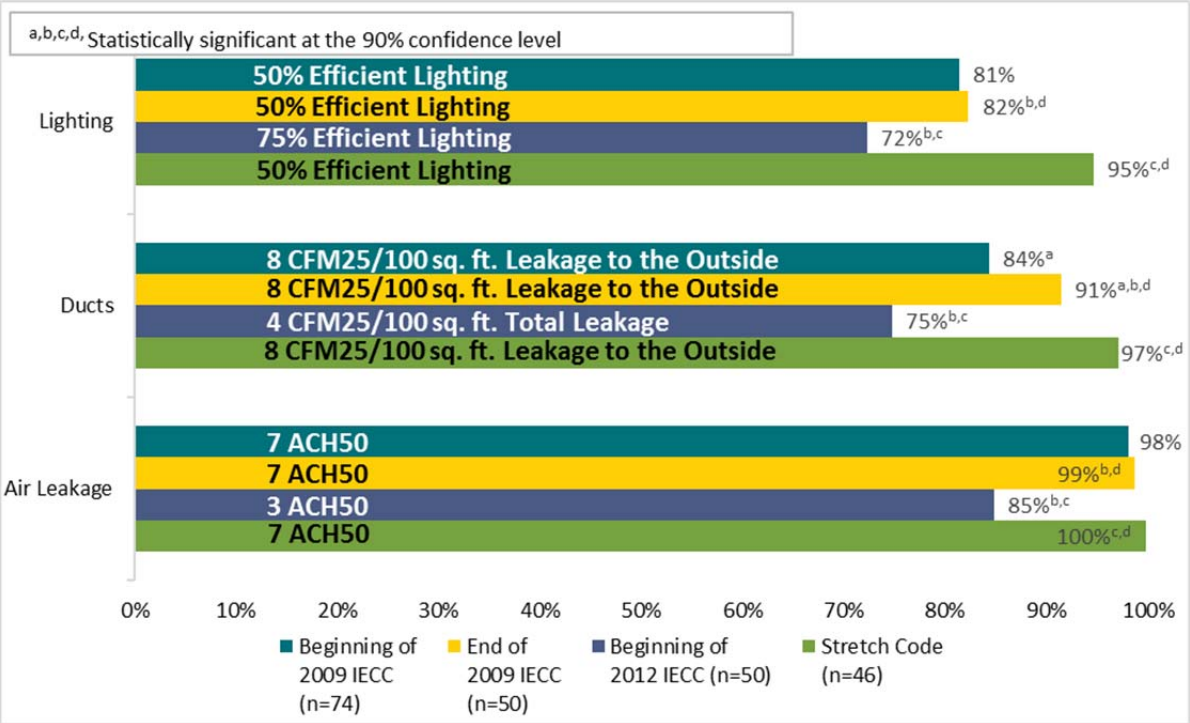
that home would be given an 80% compliance score because the as-built home has a consumption value that is 20% higher than the code-built home. For this reason, these compliance values do not align with those presented in Volume 2 of this report, which focuses on the number of homes that meet or exceed a code requirement. Please see Section 2.2 for more details.

Figure 7 highlights the measure-level findings for lighting, ducts, and air leakage.

- Lighting, duct leakage, and air leakage requirements all underwent a change between the 2009 IECC and 2012 IECC. These requirements clearly had an effect on compliance because homes built at the beginning of the 2012 IECC cycle have significantly lower compliance scores for these measures than do homes that were built at the end of the 2009 IECC cycle.
- Surprisingly, compliance for homes built at the end of the 2009 IECC is similar to compliance for homes built under the stretch code for ducts and air leakage. This is somewhat unexpected given that the stretch code requires a HERS rater to test the performance of these components and the house overall. The 2009 IECC requires performance testing for duct systems, but it is optional to test for air leakage. It's surprising that compliance with these measures, in particular air leakage, is so similar between these two groups of homes considering the differences in testing requirements and HERS rater involvement. The similarity between the two samples is partially due to the fact that, under the MA-REC approach, homes receive full points for a given measure regardless of whether they meet the code requirement by a little bit or a by a lot. These measures have high compliance rates under both of these samples and therefore the overall compliance is not significantly different. That said, the raw data show that stretch code homes are in fact more efficient than homes built at the end of the 2009 IECC cycle for these building components.[27]

[27] Non-program homes built under the stretch code have an unweighted average air leakage rate of 3.4 air changes per hour at 50 Pascals (ACH50) and an unweighted average duct leakage to the outside rate of 4.2 cubic feet per minute at 25 Pascals per 100 ft^2 (CFM25/100 ft^2). Homes built at the end of the 2009 IECC have an unweighted average air leakage rate of 4.8 ACH50 and an unweighted average duct leakage to the outside rate of 6.5 CFM25/100 ft^2.

Figure 7: MA-REC Statewide Measure-Level Compliance—Lighting, Ducts, and Air Leakage*



*Homes built at the end of the 2006 IECC cycle are excluded from this figure because the 2006 IECC did not have air leakage testing, duct leakage testing, or lighting requirements.

Figure 8 shows the measure-level compliance for frame floor insulation and installation, ceiling insulation and installation, and above-grade wall insulation and installation.

- Compliance with ceiling insulation requirements has steadily improved over time. Compliance even improved from the end of the 2009 IECC cycle to the beginning of the 2012 IECC cycle when the code requirements shifted from R-38 to R-49. While the change over the 2009 IECC cycle is not statistically significant, the improvement from the end of the 2009 IECC cycle to the beginning of the 2012 IECC cycle is significant at the 90% confidence level.
- Compliance with frame floor insulation requirements (which have not changed from the 2006 IECC to the 2012 IECC) has steadily improved over time. Homes built under the stretch code have significantly higher compliance with these requirements than homes built at the end of the 2006 IECC cycle and homes built at the beginning of the 2009 IECC cycle.
- Compliance with wall insulation requirements is significantly higher at the end of the 2009 IECC cycle than it was at the beginning of that cycle.

Figure 8: MA-REC Statewide Measure-Level Compliance—Frame Floors, Ceilings, and Walls

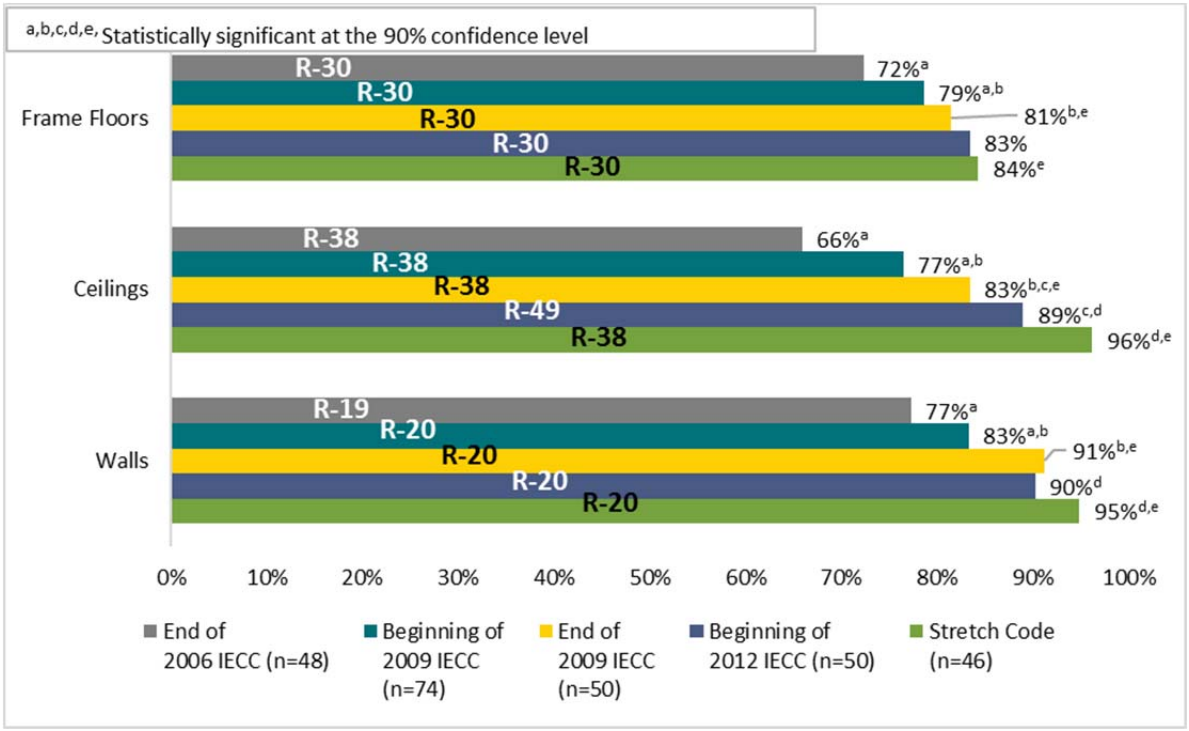
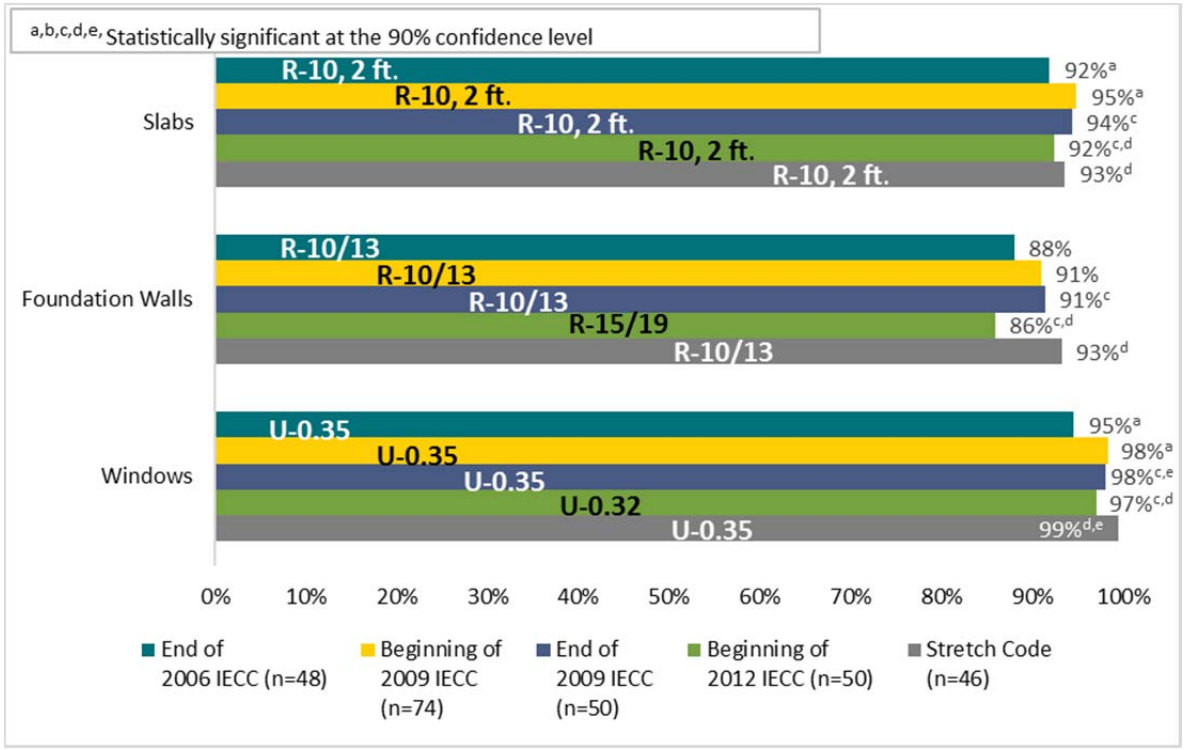


Figure 9 presents the measure-level compliance findings for slabs, foundation walls, and windows. As shown, these measures display relatively high compliance levels under the MA-REC approach. There are no significant differences between compliance levels for these measures at the beginning and end of code cycles.

Figure 9: MA-REC Statewide Measure-Level Compliance—Slabs, Foundation Walls, and Windows



3.1.1 Potential Savings from Compliance Enhancement

This section presents the gross technical potential savings from increasing non-compliant measures to the 2012 IECC and 2009 IECC (for stretch code homes) prescriptive code levels in all homes (both program and non-program) built under the 2012 IECC and stretch code. In other words, this section presents the potential savings from achieving 100% compliance with the prescriptive requirements for measures considered in the MA-REC approach. It is important to keep in mind that many factors influence compliance (e.g., natural market adoption, CCSI training efforts, other code advocacy training efforts, spillover from the RNC program, etc.) and these savings values are not indicative of what the CCSI could achieve, but rather what the entire market can achieve at this moment in time.

Specifically, the Team compared the as-built energy models to the prescriptive code-built models and looked at the measure-level savings difference for non-compliant measures. These values were weighted to represent the relative home sizes that were identified in the 2012 IECC and stretch code samples.

As previously mentioned, the MA-REC approach compares all measures to prescriptive code requirements and as a result may overestimate the actual savings from 100% compliance for homes that use the trade-off or performance compliance paths. Under the trade-off and performance paths some measures are allowed to be non-compliant assuming a separate measure counteracts that by being over-compliant.

Table 6 presents the gross technical potential savings for homes built under the 2012 IECC. Savings, are shown, by measure, for non-program homes, program homes, and statewide. Each measure is listed as being either a mandatory requirement or a requirement that is subject to trade-offs in the UA trade-off or performance compliance paths. The total savings are shown two ways, with and without trade-offs; the total that accounts for trade-offs includes the impacts of above code practices on potential savings which reduces the overall savings potential. The savings for non-program homes are broken down by compliance path and then shown for the sample overall. As shown, homes utilizing the prescriptive and trade-off paths show higher savings potential than homes using the performance path. Air leakage, duct leakage, and lighting—all mandatory code requirements under the 2012 IECC—show the largest savings potential. Statewide the potential savings from bringing all below-code measures to code is 18%; this drops to 15% when the impact of measures that exceed the prescriptive code requirements are considered.

Table 6: Gross Technical Potential Savings for 2012 IECC Homes (% of Baseline MMBtu Consumption)

Building System	Requirement	2012 IECC Non-Program Homes				Program Homes	Statewide
		Pres.	Trade-Off	Perf.	Total		
Air Leakage	Mandatory	5%	5%	1%	4%	0%	3%
Duct Leakage	Mandatory	6%	5%	2%	4%	2%	4%
Lighting	Mandatory	5%	4%	4%	4%	0%	3%
Above Grade Walls	Path dependent	4%	2%	2%	2%	1%	2%
Windows	Path dependent	1%	1%	0%	1%	0%	1%
Ceiling	Path dependent	1%	3%	1%	2%	1%	1%
Frame Floors	Path dependent	2%	2%	2%	2%	1%	2%
Foundation Walls	Path dependent	3%	0%	2%	2%	1%	1%
Slabs	Path dependent	0%	0%	1%	0%	0%	0%
Total (No Trade-Offs)		26%	22%	14%	21%	6%	18%
Total (With Trade-Offs)		24%	20%	10%	19%	3%	15%

Table 7 shows the technical potential savings for stretch code homes. Once again, savings are presented for non-program homes, program homes, and statewide. None of the savings are broken down by compliance path as the stretch code requires all homes to use a performance path for compliance. The statewide savings for stretch code homes are minimal (5% with no trade-offs and 0% with trade-offs). This is largely due to the fact that stretch code homes have such a high penetration (77%) in the RNC program. It should be noted that stretch code homes were compared to the 2009 IECC prescriptive requirements as that is currently the base code that the stretch code is built off of. The stretch code is set to be updated, based on the 2015 IECC, in January of 2017. This change will likely lead to an uptick in potential savings associated with stretch code homes. In particular, air leakage, duct leakage, and lighting (all mandatory requirements), will have increased efficiency requirements with this change.

Table 7: Gross Technical Potential Savings for Stretch Code Homes (% of Baseline MMBtu Consumption)

Building System	Requirement	Non-Program Homes	Program Homes	Statewide
Air Leakage	Mandatory	0%	0%	0%
Duct Leakage	Mandatory	2%	0%	1%
Lighting	Path dependent*	3%	0%	1%
Above Grade Walls	Path dependent	1%	1%	1%
Windows	Path dependent	1%	0%	0%
Ceiling	Path dependent	1%	0%	0%
Frame Floors	Path dependent	1%	1%	1%
Foundation Walls	Path dependent	0%	1%	0%
Slabs	Path dependent	0%	0%	0%
Total (No Trade-Offs)		9%	4%	5%
Total (With Trade-Offs)		2%	0%	0%

*This is a path dependent requirement under the 2009 IECC but is a mandatory requirement under the 2015 IECC which stretch code will soon be based on.

3.2 PNNL Approach Findings

Figure 10 presents non-program compliance rates using the PNNL approach. The compliance rates are presented for the overall sample of homes within each study group as well as for the various compliance paths that builders can use to achieve compliance in Massachusetts. The Team only populated PNNL checklists for non-program homes and therefore the non-program results are highlighted in this section. Section 3.2.1 includes a statewide compliance estimate using the PNNL approach by applying estimates of compliance for RNC program homes.

Using the PNNL approach, compliance rates are significantly higher at the end of the code cycles (76% at the end of the 2006 IECC cycle and 70% at the end of the 2009 IECC cycle) than they are at the beginning of a code cycle (63% at the beginning of the 2009 IECC cycle and 64% at the beginning of the 2012 IECC). This may be partially due to the fact that it takes time for builders and subcontractors to understand and adapt to new code requirements.

Figure 10: Non-Program Compliance Rates by Compliance Path Using the PNNL Approach

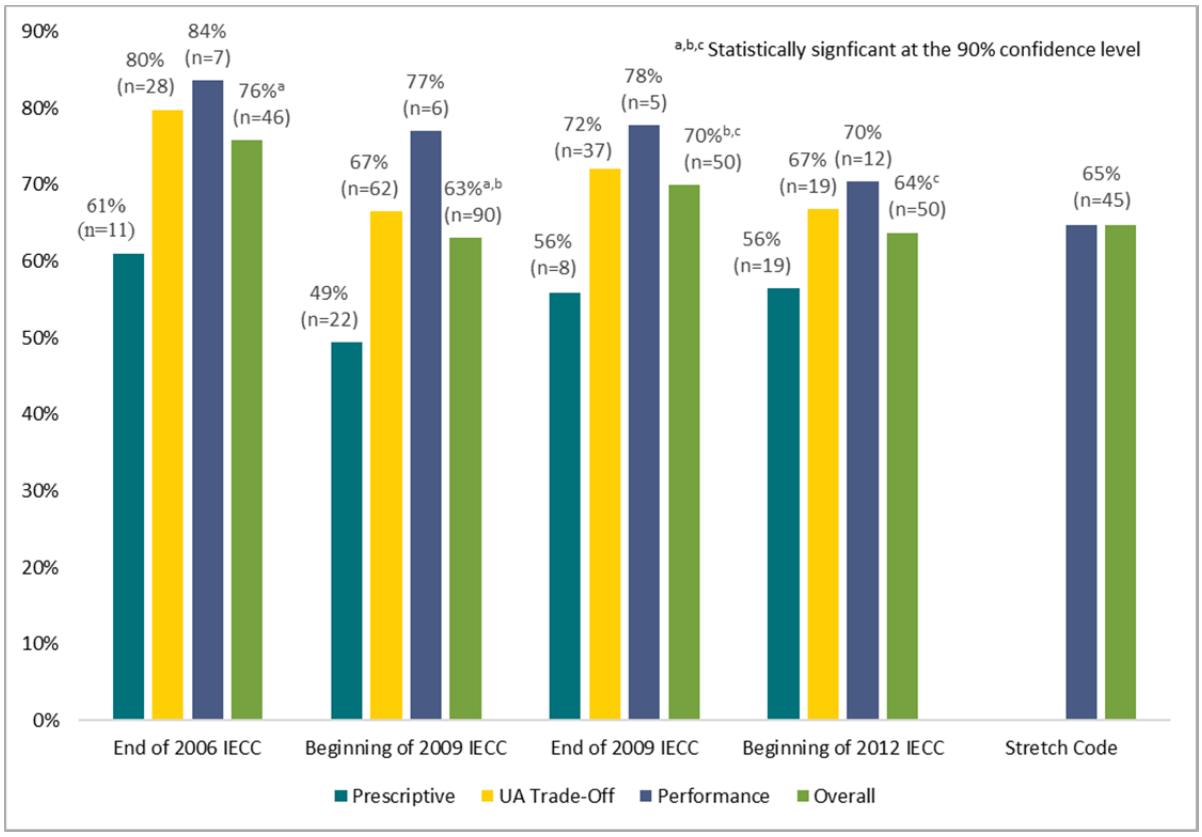


Figure 11 presents the distribution of compliance paths for each of the non-program samples included in this study. As shown, the majority of builders within the 2006 IECC and 2009 IECC sample groups use the UA trade-off approach (typically using the REScheck™ software) to show compliance with the energy code. This compliance path allows builders to exceed the code in certain areas and fall below the code in others so long as the overall efficiency of the building is not compromised.[28] The performance path works in a very similar way. Homes built under the 2012 IECC show a drop in the use of the UA trade-off approach, which is associated with a rise in the use of the prescriptive and performance paths.

Figure 11: Distribution of Compliance Paths for Non-Program Homes

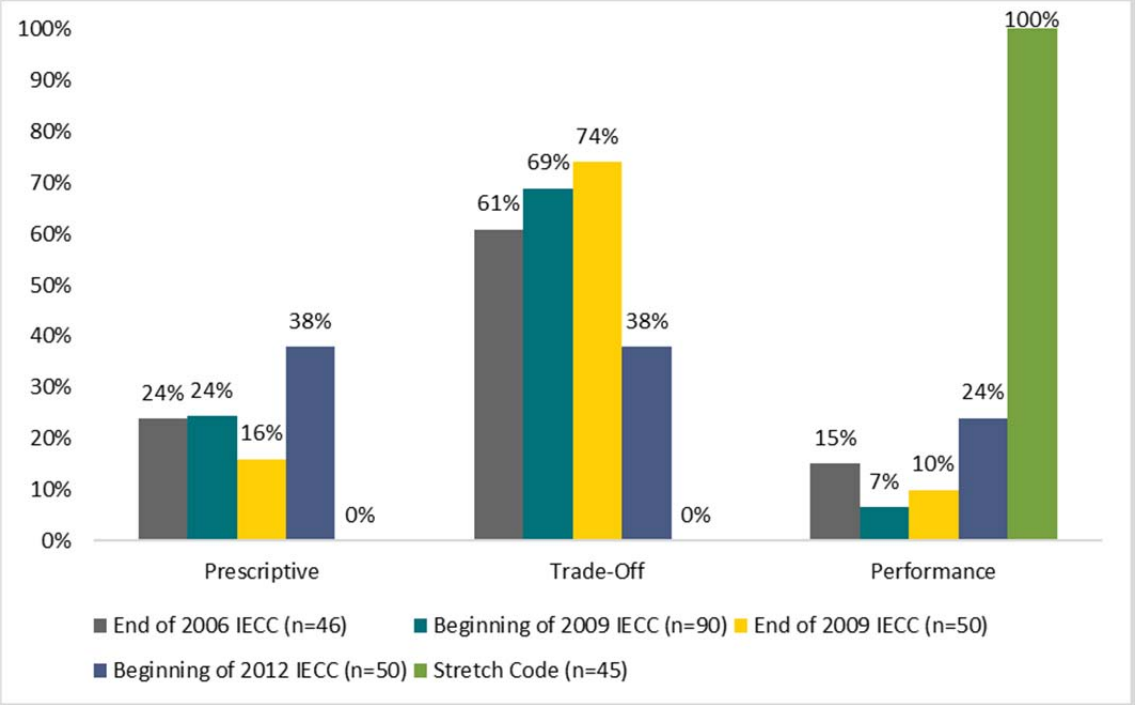


Table 8 presents the average non-program scores, across all codes, for different categories of checklist items that are included in the PNNL methodology. Most of these categories include numerous checklist items. Additional details on the number of checklist items within each group and the percentage of checklist items that were verifiable can be found in Appendix B. Some interesting findings from Table 8 are listed below.

- Compliance with the air leakage requirement increased significantly from 67% to 92% from the beginning to the end of the 2009 IECC cycle.

[28] Under the 2006 IECC, REScheck allowed trade-offs between the shell and mechanical equipment efficiencies; beginning with the 2009 IECC, REScheck only allowed trade-offs with envelope measures.

  - The 2012 IECC includes more stringent air leakage requirements and, as a result, the compliance score dropped significantly from 92% at the end of the 2009 IECC cycle to 62% at the beginning of the 2012 IECC cycle.
- Compliance rates for the lighting requirements are surprisingly low, regardless of the code that homes were built under. Note the drop from the end of the 2009 IECC cycle to the beginning of the 2012 IECC cycle—this is due to an enhanced lighting requirement in the new code.[29]

Table 8: Average Non-Program PNNL Checklist Scores by Code and Requirement Category

Building System (checklist items)	End of 2006 IECC (n=46)	Beginning of 2009 IECC (n=90)	End of 2009 IECC (n=50)	Beginning of 2012 IECC (n=50)	Stretch Code (n=45)
Above-Grade Walls	91%	68%[d]	79%[bd]	77%	64%[b]
Windows	100%	100%	99%	100%	100%
Air Leakage	n/a	67%[d]	92%[ad]	62%[ac]	94%[c]
HVAC	67%	31%[d]	57%[d]	49%[c]	63%[c]
Lighting	n/a	10%[d]	41%[d]	26%[c]	51%[c]
Ceilings	85%	69%	60%[a]	71%[ac]	54%[c]
Frame Floors	78%	67%[d]	78%[bd]	80%[c]	61%[c]
Foundation Walls	93%	87%	89%[a]	71%[a]	83%
Slabs*	--	–	90%	77%	76%
Other		0%[d]	54%[d]	51%	49%

[a,b,c,d] Statistically significant at the 90% confidence level.
*Slabs were included with foundation walls in the previous study that assessed the end of the 2006 IECC cycle.

3.2.1 Statewide PNNL Compliance with Program Home Assumptions

All of the information above represents single-family homes in Massachusetts that did not participate in the RNC program. In order to develop an estimate of statewide compliance, program homes need to be accounted for. Using 2015 program records the Team estimates that the program has an overall penetration rate of 42%, 24% in non-stretch code towns and 77% in stretch code towns.[30] In order to estimate statewide compliance using the PNNL approach the Team used these penetration rates along with assumptions about program home compliance rates to develop a range of compliance estimates that capture both program and non-program single-family homes built at the end of the 2009 IECC

[29] Compliance with the lighting requirements are much lower under the PNNL approach than they are under the MA-REC approach. The PNNL approach assesses whether or not homes meet the lighting requirements on a yes/no basis. The MA-REC approach compliance scores do not represent the proportion of homes that comply with the code. Instead, these compliance scores represent the percent change in estimated energy consumption between as-built and code-built energy models
[30] These penetration rates were calculated by comparing the single-family homes in the 2015 RNC program to 2013 permit activity for single-family new homes in Massachusetts.

cycle, the beginning of the 2012 IECC cycle, and under the stretch code.[31] Specifically, we assumed compliance rates of 90%, 95%, and 100% for program homes built under each of the code cycles considered in this study. Including program homes in the compliance assessment significantly increases compliance depending on the code cycle being considered, the estimated compliance rate for program homes, and the single-family program penetration that is assumed (Table 9).

Table 9: Statewide PNNL Compliance Assuming Various Compliance Scores for Program Homes

	End of 2006 IECC (n=46)	Beginning of 2009 IECC (n=90)	End of 2009 IECC (n=50)	Beginning of 2012 IECC (n=50)	Stretch Code (n=45)
90% Compliance for Program Homes	78%	66%	75%	70%	84%
95% Compliance for Program Homes	78%	67%	76%	71%	88%
100% Compliance for Program Homes	79%	67%	77%	73%	92%

[31] The same approach was taken in 2011 when statewide compliance estimates were developed for homes built at the end of the 2006 IECC cycle and the beginning of the 2009 IECC cycle. At that time, the penetration rate for single-family homes in the RNC program was only 12%.

Appendix A Code Requirements

This section presents the prescriptive code requirements associated with the 2006 IECC, the 2009 IECC, the 2012 IECC, and the 2015 IECC, as well as a brief summary of the current and upcoming stretch code requirements.

Table 10: 2006 IECC Insulation and Fenestration Requirements by Component[a]

Climate Zone	Fenestration U-Factor	Skylight [b] U-Factor	Glazed Fenestration SHGC	Ceiling R-value	Wood Frame Wall R-value	Mass Wall R-value	Floor R-Value	Basement [c] Wall R-Value	Slab [d] R-Value & Depth	Crawl Space [c] Wall R-value
1	1.20	0.75	0.40	30	13	3	13	0	0	0
2	0.75	0.75	0.40	30	13	4	13	0	0	0
3	0.65	0.65	0.40[e]	30	13	5	19	0	0	5/13
4 except Marine	0.40	0.60	NR	38	13	5	19	10/13	10,2 ft	10/13
5 and Marine 4	**0.35**	**0.60**	**NR**	**38**	**19 or 13+5[g]**	**13**	**30[f]**	**10/13**	**10,2 ft**	**10/13**
7	0.35	0.60	NR	49	19 or 13+5[g]	15	30[f]	10/13	10,4 ft	10/13
7 and 8	0.35	0.60	NR	49	21	19	30[f]	10/13	10,4 ft	10/13

a. R-values are minimums. U-factors and SHGC are maximums. R-19 shall be permitted to be compressed into a 2 × 6 cavity.
b. The fenestration U-factor column excludes skylights. The SHGC column applies to all glazed fenestration.
c. The first R-value applies to continuous insulation, the second to framing cavity insulation; either insulation meets the requirement.
d. R-5 shall be added to the required slab edge R-values for heated slabs.
e. There are no SHGC requirements in the Marine zone.
f. Or insulation sufficient to fill the framing cavity, R-19 minimum.
g. "13+5" means R-13 cavity insulation plus R-5 insulated sheathing. If structural sheathing covers 25 percent or less of the exterior, insulating sheathing is not required where structural sheathing is used. If structural sheathing covers more than 25 percent of exterior, structural sheathing shall be supplemented with insulated sheathing of at least R-2.

Table 11: 2009 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	1.2	0.75	0.30	30	13	3/4	13	0	0	0
2	0.65[j]	0.75	0.30	30	13	4/6	13	0	0	0
3	0.50[j]	0.65	0.30	30	13	5/8	19	5/13[f]	0	5/13
4 except Marine	0.35	0.60	NR	38	13	5/10	19	10/13	10, 2 ft	10/13
5 and Marine 4	**0.35**	**0.60**	**NR**	**38**	**20 or 13+5[h]**	**13/17**	**30[g]**	**10/13**	**10, 2 ft**	**10/13**
7	0.35	0.60	NR	49	20 or 13+5[h]	15/19	30[g]	15/19	10, 4 ft	10/13
7 and 8	0.35	0.60	NR	49	21	19/21	30[g]	15/19	10, 4 ft	10/13

a. R-values are minimums. U-factors and SHGC are maximums. R-19 batts compressed into a nominal 2x6 framing cavity such that the R-value is reduced by R-1 or more shall be marked with the compressed batt R-value in addition to the full thickness R-value.
b. The fenestration U-factor column excludes skylights. The SHGC column applies to all glazed fenestration.
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. "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. "13+5" means R-13 cavity insulation plus R-5 insulated sheathing. If structural sheathing covers 25 percent or less of the exterior, insulating sheathing is not required where structural sheathing is used. If structural sheathing covers more than 25 percent of exterior, structural sheathing shall be supplemented with insulated sheathing of at least R-2.
i. The second R-value applies when more than half the insulation is on the interior of the wall.
j. For impact rated fenestration complying with SectionR301.2.1.2 of the International Residential Code or Section 1608.1.2 of the International Building code, the maximum U-factor shall be 0.75 in Zone 2 and 0.65 in Zone 3.

Table 12: 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.

Stretch Code Requirements

A summary of the Massachusetts stretch energy code requirements can be found here: http://www.mass.gov/eea/docs/doer/green-communities/grant-program/stretch-code-summary-jun20-2011.pdf

The current stretch code amends the 2009 IECC requirements to achieve approximately a 20% improvement in building energy performance. The stretch code requires new single-family homes to meet the following HERS index requirements:

- A HERS index of 65 or less for homes that are 3,000 ft^2 or lager
- A HERS index of 70 or less for homes that are less than 3,000 ft^2

In addition to these performance-based requirements, the stretch code requires that new single-family homes meet the mandatory provisions of the 2009 IECC and complete the ENERGY STAR Thermal Enclosure Checklist.

The stretch code has been updated and enforcement will begin in January of 2017. The updated stretch code requirements can be found in the following links:

- http://www.mass.gov/eopss/docs/dps/buildingcode/inf4/bbrs-chapter51-11-residential-energy-efficiency-06142016.pdf
- http://www.mass.gov/eopss/docs/dps/buildingcode/inf4/bbrs-780-cmr-appendix115aa-aug16.pdf

The updated stretch code requires a HERS index of 55 for new homes with no renewable energy sources. In addition, the updated code requires that homes be certified to either ENERGY STAR v3.1 or be modeled using Passive House Institute US (PHIUS) approved software and have specific space heat demand of less than or equal to 10 kBtu/ft^2/year.

B Appendix B Supplemental PNNL Results

This appendix presents supplemental information for the PNNL compliance approach. Specifically, Table 13 through Table 17 show the average PNNL compliance scores for groups of requirements that are found in the PNNL checklist. Results are presented for each of the code groups considered in this study as well as the various compliance paths that were investigated as part of the PNNL approach. The "Percent Verifiable" column reflects how often the homes within a given compliance group were verifiable; the lower the percent verifiable, the less precise the compliance estimate is for an item group.

Table 13: End of 2006 IECC Average PNNL Checklist Category Scores

Building System	# of Checklist Items	Percent Verifiable	All Homes (n=46)	Prescriptive (n=11)	UA Trade-Off (n=28)	Performance (n=7)
Above-Grade Walls	6	100%	91%	91%	93%	79%
Windows	12	29%	100%	--	100%	100%
Air Leakage	4	5%	89%	--	83%	100%
HVAC	10	51%	67%	72%	63%	76%
Ceilings	4	91%	85%	56%	89%	100%
Frame Floors	2	100%	78%	52%	85%	93%
Foundation Walls	13	70%	93%	67%	96%	100%
Other	3	67%	4%	9%	2%	7%

Table 14: Beginning of 2009 IECC Average PNNL Checklist Category Scores

Building System	# of Checklist Items	Percent Verifiable	All Homes (n=90)	Prescriptive (n=22)	UA Trade-Off (n=62)	Performance (n=6)
Above-Grade Walls	6	100%	68%	38%	77%	75%
Windows	9	64%	100%	100%	100%	100%
Air Leakage	5	15%	67%	59%	69%	83%
HVAC	12	40%	31%	30%	30%	51%
Lighting	1	99%	10%	18%	7%	0%
Ceilings	5	87%	69%	56%	71%	89%
Frame Floors	2	100%	67%	55%	72%	69%
Foundation Walls	8	98%	87%	81%	88%	–
Slabs	3	–	–	–	–	–
Other	8	0%	0%	0%	0%	0%

Table 15: End of 2009 IECC Average PNNL Checklist Category Scores

Building System	# of Checklist Items	Percent Verifiable	All Homes (n=50)	Prescriptive (n=8)	UA Trade-Off (n=37)	Performance (n=5)
Above-Grade Walls	6	100%	79%	56%	84%	83%
Windows	9	69%	99%	100%	98%	100%
Air Leakage	5	75%	92%	87%	91%	100%
HVAC	12	87%	57%	48%	57%	74%
Lighting	1	98%	41%	25%	45%	40%
Ceilings	5	99%	60%	49%	61%	64%
Frame Floors	2	100%	78%	75%	78%	80%
Foundation Walls	8	96%	89%	78%	90%	89%
Slabs	3	29%	90%	0%	100%	100%
Other	8	47%	54%	40%	57%	46%

Table 16: Beginning of 2012 IECC Average PNNL Checklist Category Scores

Building System	# of Checklist Items	Percent Verifiable	All Homes (n=50)	Prescriptive (n=19)	UA Trade-Off (n=19)	Performance (n=12)
Above-Grade Walls	6	100%	77%	64%	85%	83%
Windows	9	49%	100%	100%	100%	100%
Air Leakage	6	59%	62%	55%	62%	74%
HVAC	14	81%	49%	51%	46%	52%
Lighting	1	100%	26%	26%	26%	25%
Ceilings	6	98%	71%	62%	75%	80%
Frame Floors	2	100%	80%	78%	82%	82%
Foundation Walls	8	98%	71%	43%	91%	89%
Slabs	3	31%	77%	25%	100%	100%
Other	10	46%	51%	39%	54%	66%

Table 17: Stretch Code Average PNNL Checklist Category Scores

Building System	# of Checklist Items	Percent Verifiable	Performance (n=45)
Above-Grade Walls	6	100%	64%
Windows	9	80%	100%
Air Leakage	5	78%	94%
HVAC	12	85%	63%
Lighting	1	100%	51%
Ceilings	5	99%	54%
Frame Floors	2	100%	61%
Foundation Walls	8	96%	83%
Slabs	3	30%	72%
Other	8	45%	49%

C Appendix C Supplemental MA-REC Approach Results

Table 18 through Table 22 show the measure-level compliance rates for each sample broken down by non-program homes, program homes, and statewide. These tables are meant to supplement the statewide measure-level findings presented in the Executive Summary and in Section 3.

Table 18: MA-REC Compliance for Homes Built at the End of the 2006 IECC*

Building System	Requirement	Non-Program Homes	Program Homes	Statewide
Air Leakage	Mandatory	n/a	n/a	n/a
Duct Insulation	Path dependent	89%	96%	90%
Lighting	Mandatory	n/a	n/a	n/a
Above Grade Walls	Path dependent	77%	82%	77%
Windows	Path dependent	94%	100%	95%
Ceiling	Path dependent	62%	92%	66%
Frame Floors	Path dependent	72%	77%	72%
Foundation Walls	Path dependent	87%	94%	88%
Slabs	Path dependent	91%	97%	92%
Total Compliance		81%	91%	92%

*Air leakage, lighting, and duct leakage were not specific code requirements under the 2006 IECC.

Table 19: MA-REC Compliance for Homes Built at the Beginning of the 2009 IECC*

Building System	Requirement	Non-Program Homes	Program Homes	Statewide
Air Leakage	Mandatory	98%	100%	98%
Duct Leakage	Mandatory	82%	99%	84%
Lighting	Path dependent*	79%	100%	81%
Above Grade Walls	Path dependent	82%	91%	83%
Windows	Path dependent	98%	100%	98%
Ceiling	Path dependent	74%	94%	77%
Frame Floors	Path dependent	78%	86%	79%
Foundation Walls	Path dependent	91%	94%	91%
Slabs	Path dependent	94%	97%	95%
Total Compliance		86%	96%	87%

*Under the 2009 IECC the lighting requirement applies to prescriptive and UA trade-off homes, but not performance path homes.

Table 20: MA-REC Compliance for Homes Built at the End of the 2009 IECC*

Building System	Requirement	Non-Program Homes	Program Homes	Statewide
Air Leakage	Mandatory	98%	100%	99%
Duct Leakage	Mandatory	89%	100%	91%
Lighting	Path dependent*	77%	100%	82%
Above Grade Walls	Path dependent	90%	95%	91%
Windows	Path dependent	97%	100%	98%
Ceiling	Path dependent	79%	97%	83%
Frame Floors	Path dependent	80%	87%	81%
Foundation Walls	Path dependent	90%	94%	91%
Slabs	Path dependent	94%	96%	94%
Total Compliance		89%	97%	91%

*Under the 2009 IECC the lighting requirement applies to prescriptive and UA trade-off homes, but not performance path homes.

Table 21: MA-REC Compliance for Homes Built at the Beginning of the 2012 IECC

Building System	Requirement	Non-Program Homes	Program Homes	Statewide
Air Leakage	Mandatory	81%	96%	85%
Duct Leakage	Mandatory	73%	80%	75%
Lighting	Mandatory	64%	100%	72%
Above Grade Walls	Path dependent	89%	94%	90%
Windows	Path dependent	96%	100%	97%
Ceiling	Path dependent	88%	92%	89%
Frame Floors	Path dependent	81%	89%	83%
Foundation Walls	Path dependent	84%	92%	86%
Slabs	Path dependent	92%	94%	92%
Total Compliance		83%	94%	86%

Table 22: MA-REC Compliance for Homes Built Under the Stretch Code*

Building System	Requirement	Non-Program Homes	Program Homes	Statewide
Air Leakage	Mandatory	99%	100%	100%
Duct Leakage	Mandatory	90%	99%	97%
Lighting	Path dependent*	78%	100%	95%
Above Grade Walls	Path dependent	94%	95%	95%
Windows	Path dependent	98%	100%	99%
Ceiling	Path dependent	92%	97%	96%
Frame Floors	Path dependent	86%	84%	84%
Foundation Walls	Path dependent	93%	93%	93%
Slabs	Path dependent	92%	94%	93%
Total Compliance		93%	97%	96%

*Under the 2009 IECC the lighting requirement applies to prescriptive and UA trade-off homes, but not performance path homes.

Table 23 presents the MA-REC approach compliance findings broken down by compliance path. Stretch code homes are not included in this table because all homes are considered to use the performance path under the stretch code. As shown, in terms of overall compliance, there are no statistically significant differences by compliance path for homes built at the end of the 2006 IECC cycle or homes built at the beginning of the 2009 IECC cycle. Homes built at the end of the 2009 IECC cycle show significantly higher compliance under the performance path (92%) than the prescriptive path (86%), though only five homes used the performance path. Similarly, homes built at the beginning of the 2012 IECC have significantly higher compliance under the performance path (88%) than they do under the prescriptive path (82%) and the UA trade-off path (81%).

Table 23: MA-REC Score System Compliance by Code and Path

NMR Compliance	IECC 2006			Early IECC 2009			Late IECC 2009			Early IECC 2012		
	Pres. (n=9)	Trade (n=28)	Perf. (n=7)	Pres. (n=13)	Trade (n=49)	Perf. (n=4)	Pres. (n=8)	Trade (n=37)	Perf. (n=5)	Pres. (n=19)	Trade (n=19)	Perf. (n=12)
AGW	80%	77%	70%	77%	83%	84%	82%^{xz}	91%^{x}	96%^{z}	87%	90%	92%
Windows	92%	93%	96%	98%	98%	98%	97%	97%	100%	95%^{z}	96%	98%^{z}
Air Leakage	–	–	–	100%	97%	100%	94%	99%	100%	78%^{z}	77%^{y}	93%^{yz}
Ducts	90%	88%	89%	88%	80%	83%	86%	89%	92%	71%	67%^{y}	85%^{y}
Lighting	–	–	–	80%	78%	81%	80%^{xz}	77%^{x}	70%^{z}	64%	63%	63%
Ceilings	58%	62%	62%	70%	74%	72%	72%	79%	93%	95%^{x}	79%^{xy}	91%^{y}
F. Floors	65%	73%	71%	68%^{x}	81%^{x}	67%	81%	79%	83%	81%	82%	82%
Found. Wall	91%	88%	86%	91%	89%^{y}	100%^{y}	91%	91%	87%	74%	91%	88%
Slabs	90%	90%	95%	94%	93%^{y}	100%^{y}	89%	95%	90%	91%	92%	93%
TOTAL	81%	81%	80%	85%	86%	87%	86%^{z}	89%	92%^{z}	82%^{z}	81%^{y}	88%^{yz}

^{x,y,z} Statistically significant difference at 90% C.I. x: Prescriptive and UA-Trade-off, y: UA Trade-Off and Performance, z: Prescriptive and Performance