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# Massachusetts Electric and Gas Program Administrators

## Code Compliance Results for Single-Family Non-Program Homes in Massachusetts

**September 2, 2014**

**Prepared by:**

**NMR Group, Inc.**

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Part of the Special and Cross-Cutting Evaluation Program Area

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# 1. INTRODUCTION

This report summarizes the results of a code compliance assessment for single-family non-program homes[1] in Massachusetts conducted by NMR, which is part of the Tetra Tech Cross-Cutting evaluation team. Specifically, this report summarizes code compliance rates for single-family non-program homes built at the end of the 2006 International Energy Conservation Code (IECC) cycle and the beginning of the 2009 IECC cycle.

The Massachusetts Program Administrators (PAs) recently implemented a Code Compliance Support Initiative (CCSI) through which they will be providing trainings to various market actors (e.g., code officials, builders) with the goal of improving statewide code compliance. The compliance scores presented in this report provide two reference points for the CCSI: compliance at the beginning and end of a code cycle with no direct influence from the PAs. These compliance scores can be used as comparison points for future compliance studies that do account for PA activity through the CCSI. Comparing compliance scores before and after the implementation of the CCSI should help evaluators assess the influence of the CCSI on future compliance scores.

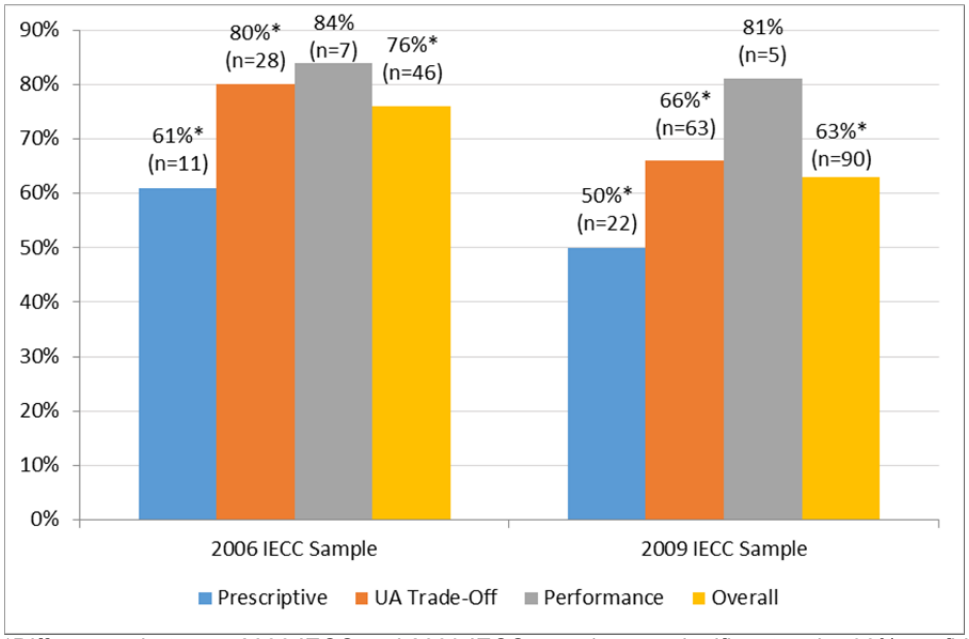
[1] *Non-program* refers to homes that did not participate in the residential new construction program sponsored by the Massachusetts PAs.

# 2. SUMMARY OF RESULTS

This study used code compliance checklists developed by Pacific Northwest National Laboratory (PNNL) to develop compliance scores for single-family non-program homes built at the end of the 2006 IECC cycle and the beginning of the 2009 IECC cycle. The results are representative of the average house-level compliance scores using the PNNL checklists. 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 the total points for items marked either compliant or not compliant. These scores show partial compliance and are not indicative of compliance rates on a yes/no basis, in which homes would be compliant only if they met 100% of the applicable requirements.

Homes built at the end of the 2006 IECC cycle show significantly higher overall compliance scores (76%) than homes built at the beginning of the 2009 IECC cycle (63%) (Figure 2-1). The same is true for specific compliance paths: homes built at the end of the 2006 IECC cycle have significantly higher compliance levels than homes built at the beginning of the 2009 IECC cycle under both the prescriptive path (61% vs. 50%, respectively) and the UA[2] trade-off approach (80% vs. 66%, respectively).

**Figure 2-1. Average Compliance Score by Compliance Path**




*Differences between 2006 IECC and 2009 IECC samples are significant at the 90% confidence level.

These results are not particularly surprising, given that (1) significant changes took place when the 2009 IECC was implemented (see Section 6.1) and (2) the homes in the 2006 IECC sample were built at the end of the code cycle, while the homes in the 2009 IECC sample

[2] U-factor*area.

were built at the beginning of the cycle. One possible reason that homes built at the end of the 2006 IECC cycle show higher compliance is that builders and subcontractors had three years to familiarize themselves with the code before constructing these homes. Builders and subcontractors constructing homes at the beginning of the 2009 IECC cycle were likely just beginning to familiarize themselves with the new code requirements and that appears to be a cause of lower compliance levels.

The Team used REM/Rate[3] models from previous Massachusetts baseline studies to assess whether or not the 2009 IECC homes exhibiting lower compliance translates into being less efficient than the 2006 IECC homes. Table 2-1 presents a comparison of the percent change in average annual energy consumption (in MMBtu) for 2006 IECC design homes and 2006 IECC reference homes. The design home represents the as-built home (i.e., the house that was inspected) with a few modifications, while the reference home is identical to the as-built home (same square footage, configuration, volume, etc.), but it has the 2006 IECC prescriptive efficiency requirements substituted for the efficiency levels identified during the site visits. As shown, design homes from the 2006 IECC sample have an average annual energy consumption that is 2% greater than the 2006 IECC reference home, while design homes from the 2009 IECC sample have an average annual energy consumption that is 3% lower than the 2006 IECC reference home. Hence, the 2009 IECC sample homes are actually slightly more efficient than the 2006 IECC sample homes, even though the 2009 IECC homes display lower compliance with the applicable energy code. This finding supports the hypothesis that low compliance among the 2009 IECC homes is likely due to the fact that new requirements were implemented with the new energy code and builders were still familiarizing themselves with those requirements, resulting in their displaying lower compliance than homes built at the end of a code cycle.

**Table 2-1. Design Home Percent Change from 2006 IECC Reference Home**

| | 2006 IECC Sample | 2009 IECC Sample |
|---|---|---|
| *N* | *46* | *90* |
| Annual Energy Consumption (MMBtu) | 2%* | -3%* |

* Statistically significant difference at the 90% confidence level.

In both samples, homes that use the performance path show significantly higher compliance levels than homes that use either the UA trade-off or prescriptive compliance paths. Similarly, homes that use the UA trade-off approach have significantly higher compliance levels than homes that use the prescriptive compliance path (Table 6-2 and Table 6-5). Additional key findings include the following:

- More than two-thirds (67%) of the 136 homes in this study utilized the UA trade-off approach. The UA trade-off compliance path was used by 61% of homes in the 2006 IECC sample and 70% of homes in the 2009 IECC sample (Figure 6-1).
- Only 10% of homes comply with the 2009 IECC lighting requirement (Table 6-6).[4]

[3] REM/Rate is a residential energy analysis software that is commonly used to model the performance of residential buildings; the software is most notably used by the ENERGY STAR® Homes program, though not exclusively.

[4] Homes that use the performance path for compliance are exempt from the 2009 IECC lighting requirement.

All of the information presented above represents single-family homes in Massachusetts that did not participate in the Residential New Construction (RNC) Program. In order to develop a statewide compliance estimate, program homes need to be accounted for.[5] According to program records, the single-family homes that participated in the Residential New Construction Program represented 12% of all single-family homes constructed in Massachusetts in 2009 and 2010—the years that the homes in this study were likely permitted and constructed under. Table 2-2 presents estimated statewide compliance levels for the end of the 2006 IECC cycle and the beginning of the 2009 IECC cycle, assuming 90%, 95%, and 100% compliance for program homes. The evaluation team considered varying levels of compliance among program homes to display a range of possible statewide compliance estimates. As shown, compliance levels rise from 76% to 78% or 79% for homes built at the end of the 2006 IECC and from 63% to 66% or 67% for homes built at the beginning of the 2009 IECC when program homes are included in compliance calculations.

**Table 2-2. Statewide Compliance Assuming Various Compliance Scores for Program Homes**

| | End of 2006 IECC | Beginning of 2009 IECC |
|---|---|---|
| *N* | *46* | *90* |
| 90% Compliance for Program Homes | 78% | 66% |
| 95% Compliance for Program Homes | 78% | 67% |
| 100% Compliance for Program Homes | 79% | 67% |

[5] Future statewide compliance estimates will also need to account for stretch code homes. Stretch code homes were just beginning to be built at the time of the 2009 IECC inspections and thus represented a very small portion of the overall population. As a result, they were excluded from this analysis.

# 3. BACKGROUND

In 2011, NMR Group conducted on-site inspections at 150 recently constructed single-family non-program homes—fifty homes built at the end of the 2006 IECC cycle and 100 homes built at the beginning of the 2009 IECC cycle. The goal of this evaluation is to compare compliance rates between these two samples using a comparable approach for calculating compliance.

The sites from the 2006 IECC sample were inspected in the spring and summer of 2011 as part of an evaluation that served two primary purposes:

- To provide feedback on the 2006 IECC code compliance checklist developed by PNNL[6]
- To provide a comparison for the User Defined Reference Home (UDRH) inputs of the Massachusetts Residential New Construction (RNC) Program at that time.[7]

The sites from the 2009 IECC sample were inspected in the summer and fall of 2011 as part of an evaluation that updated the UDRH for the Massachusetts RNC Program.[8]

Similar data were collected for each sample, but data collection for the 2006 IECC sample included several items that are specific to the code compliance checklist developed by PNNL. The code-specific measures were not inspected for the 2009 IECC sample. Table 3-1 shows the key components of the data collection form. the blue colored column labeled “Code Checklist” was included in the data collection form only for the 2006 IECC sample. At the time of the 2009 IECC sample inspections, the Team was unaware the data would be leveraged to assess code compliance at a later date. As a result, fewer checklist items were verifiable than they would have been if code-specific measures had been inspected during the site visits for that sample.

The study based on homes built at the end of the 2006 IECC cycle included compliance calculations using the PNNL checklist, but it did not involve assessing the compliance path utilized by the homes in the sample—a critical component of the PNNL compliance methodology. The study based on homes built at the beginning of the 2009 IECC cycle did not include any compliance calculations using the PNNL methodology. As a result, the current study was necessary to develop comparable compliance estimates for these two samples.

[6] http://www.neep.org/Assets/uploads/files/emv/emv-library/2011-7-5_MA_Energy_Code_Pilot_Report.pdf.

[7] http://www.ma-eeac.org/Docs/8.1_EMV%20Page/2012/2012%20Residential%20Studies/Final%20MA%20Mini%20Baseline%20Study%20of%20Homes%20Built%20at%20the%20end%20of%20the%202006%20IECC%20Cycle%207-17-12.pdf.

[8] http://www.ma-eeac.org/Docs/8.1_EMV%20Page/2012/2012%20Residential%20Studies/Final-MA-Baseline%20Study%20of%20Single%20Family%20Residential%20New%20Contruction%208-16-12.pdf.

**Table 3-1. Data Collection Form Inputs**

| General Information | Insulation/Shell Measures | Mechanical Equipment | Test Results | Lighting & Appliances | Code Checklist* |
|---|---|---|---|---|---|
| • House type<br>• Area of conditioned space<br>• Volume of conditioned space<br>• Primary heating fuel<br>• Stories<br>• Bedrooms<br>• Thermostat type<br>• Builder type<br>• Own/Rent<br>• Evaluation region | • Exterior walls<br>• Ceilings<br>• Frame floors<br>• Rim/Band joists<br>• Windows<br>• Skylights<br>• Doors<br>• Slab Floors<br>• Foundation walls<br>• Mass walls<br>• Sunspaces | • Heating equipment<br>• Water heating equipment<br>• Cooling equipment<br>• Duct insulation<br>• Renew-ables | • Blower door results<br>• Duct blaster results | • CFL fixtures<br>• Incandescent or Halogen fixtures<br>• Fluorescent tube fixtures<br>• LED fixtures<br>• Ceiling Fans<br>• Refrigerators<br>• Dishwashers | • HVAC piping insulation<br>• Recessed fixtures<br>• Damper openings<br>• Certificate**<br>• Heat pump thermostat<br>• Circulating hot water<br>• Air sealing |

*These items were only inspected for homes built at the end of the 2006 IECC cycle.
**The 2006 IECC requires that a compliance certificate be posted on or in the electric panel of a home.

# 4. ASSESSING CODE COMPLIANCE WITH THE PNNL CHECKLIST

This section details the methodology used to populate the PNNL checklists and subsequently calculate compliance with the energy code.

## 4.1 TIMING OF INSPECTIONS

The inspections utilized for this study were conducted after the homes were occupied, thus limiting some of the items that could be visually inspected. This approach differs from the methodology outlined by the Department of Energy (DOE) for measuring statewide energy code compliance, which proposes inspecting buildings at multiple stages of construction.[9] All studies that rely on volunteers are subject to self-selection bias in that study participants may differ systematically from non-participants. In Massachusetts, the Team has longstanding concerns that builders who agree to allow on-site visits are more conscientious regarding quality construction practices and energy efficiency than are typical builders. Given these concerns, the evaluation team believes that the DOE methodology would lead to substantial self-selection bias—that is, the more conscientious builders would be more likely to participate—and hence would lead to an overestimate of compliance rates.

The Team believes that the homeowner recruitment utilized for these inspections reduces this self-selection bias. While this methodology limits the number of checklist items that can be verified onsite, the Team believes it ultimately increases the accuracy of the compliance estimate by reducing self-selection bias.

## 4.2 POPULATING THE CHECKLISTS

The 2006 and 2009 IECC PNNL checklists were used to assess energy code compliance for single-family homes in Massachusetts.[10,11] The checklists were developed by PNNL 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 IECC by 2017.[12] 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.

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

[9] http://www.energycodes.gov/sites/default/files/documents/MeasuringStateCompliance.pdf.
[10] https://www.energycodes.gov/compliance/evaluation/checklists.
[11] The 2006 IECC checklist is no longer publicly available, but it can be viewed in APPENDIX A:.
[12] http://www.gpo.gov/fdsys/pkg/BILLS-111hr1enr/pdf/BILLS-111hr1enr.pdf.

- Determine the percentage of compliant homes (those having a checklist score equal to 100%)[13]
- 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 in either sample complied with all applicable requirements and, as a result, the code compliance rate would be 0% for both 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,[14] 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 and 2009 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.[15] The 2009 IECC also includes a requirement for efficient lighting fixtures.[16]
- **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:**[17] 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 IECC performance path differs from previous editions of the IECC in that it allows *no tradeoff credit* for the use of high efficiency space heating, space cooling, or water heating equipment. The IECC 2009 is augmented in Massachusetts by a state amendment that allows for Performance-

[13] In Massachusetts, homes are required to comply with 100% of the applicable code requirements to be considered fully compliant.
[14] http://www.energycodes.gov/sites/default/files/documents /IECC2009_Residential_Nationwide_Analysis.pdf
[15] 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.
[16] The lighting requirement also applies to the UA Trade-off approach in the 2009 IECC, but it does not apply to the performance path.
[17] The annual energy costs are only calculated for space heating, space cooling, and water heating end uses.

based code compliance by achieving a Home Energy Rating System (HERS) rater-verified HERS rating of 75 or lower.[18,19]

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 non-compliant. Under the trade-off or performance approaches, certain measures may be marked as compliant, even if they do not meet the prescriptive compliance levels identified in the checklist, if they are consistent with how the builder designed the building to comply. As the 2009 IECC checklist instructions note, this is done assuming that "a valid worksheet or software report was submitted showing a compliant building."[20] The checklist is not a compliance path, but instead a means of assessing compliance. For example, if a home achieved compliance via the trade-off approach, then the builder should have submitted a REScheck report to the building department 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.

## 4.3 CHECKLIST COMPLIANCE AND RELATIVE EFFICIENCY

The IECC checklists incorporate a weighting scheme that aims to provide more emphasis on the most important energy code requirements. As stated in the 2009 IECC checklist instructions, "In an effort to focus on the most important code requirements, the checklist items have been clustered into multiple tiers. Each tier is given a different weight in determining the overall building compliance metric, with Tier 1 items receiving 3 points, Tier 2 items receiving 2 points, and Tier 3 items receiving 1 point."[21] According to PNNL, the Tier 1 requirements are 'high impact' based on the fact that they impact design energy efficiency and long-term operational energy efficiency.[22] In order to assess whether or not the checklist is truly indicative of relative energy efficiency, the Team compared compliance levels to HERS scores for each of the samples to determine whether or not the two are correlated.

[18] The HERS Index compares homes to the 2004 International Energy Conservation Code (IECC) with some modifications reflecting the 2006 IECC. Scores can range from less than zero to well over 100. A score of 100 indicates that a home was built to the specifications of the 2004 IECC (with 2006 IECC modifications), while a score of zero indicates a net zero energy home. According to the Residential Energy Services Network (RESNET), "Each 1-point decrease in the HERS Index corresponds to a 1% reduction in energy consumption compared to the HERS Reference Home."

[19] Given that HERS ratings are the basis of popular above code programs such as Energy Star Homes, LEED homes, and the MA Stretch energy code, this compliance path has seen rapid uptake. According to RESNET, HERS ratings became the most common IECC 2009 compliance path in Massachusetts in 2013, with 6,320 units certified that year. Note that many of these homes were likely certified in stretch code communities, and stretch code adoption had only just begun at the time of the onsite inspections being utilized for this study.

[20] The presence of this documentation was verified in jurisdictions where auditors physically visited the building department. In all other jurisdictions, inspectors either emailed NMR documentation or it was assumed that all inspected homes submitted the necessary paperwork to achieve compliance with the energy code, since all of the inspected homes were occupied and therefore should have an occupancy permit.

[21] https://www.energycodes.gov/compliance/evaluation/checklists.

[22] http://www.energycodes.gov/sites/default/files/documents/MeasuringStateCompliance.pdf

There is a correlation of -0.37 (90% CI = (-0.51, -0.21); p-value < 0.001) between the 2009 IECC compliance score and HERS score associated with each site. As indicated by the confidence interval and p-value, this correlation is statistically significant at the 90% confidence level. As such, the Team concludes that there is a moderate, statistically significant negative linear relationship between compliance score and HERS score for the 2009 IECC sample. As the compliance score increases, we would expect the HERS score to decrease, and vice versa. A lower HERS score indicates a more efficient home, suggesting that the 2009 IECC checklist, as populated in this study, is weighted toward the most important energy code requirements in terms of their overall impact on energy efficiency.

There is a correlation of 0.02 (90% CI = (-0.226, 0.265); p-value = 0.891) between the 2006 IECC compliance score and HERS score associated with each site. This correlation is not statistically significant at the 90% confidence level. Thus, given the magnitude of the estimated correlation, we would conclude that there is virtually no linear relationship between the 2006 IECC compliance score and HERS score.

These results appear contradictory, as the correlation between compliance scores and HERS scores in the 2009 IECC sample indicates that the checklist is weighted toward the most important measures, while the correlation in the 2006 IECC sample indicates that this is not the case. The differences between the correlation results for each sample could be partially due to the following factors:

- Some of the less significant checklist items (e.g., compliance certificate posted on the electric panel, dampers installed on all exhaust openings) were inspected for the 2006 IECC sample and not the 2009 IECC sample.
- Air leakage, a significant contributor to the overall efficiency of homes, was more verifiable in the 2009 IECC sample than it was in the 2006 IECC sample.
- The 2009 IECC allows partial credit for insulation installation, while the 2006 IECC assesses compliance with insulation installation on a yes/no basis.

# 5. FINAL SAMPLE

The final sample for this study includes 136 homes: 46 homes from the 2006 IECC sample and 90 homes from the 2009 IECC sample. Fourteen homes were excluded from the initial sample of 150 because they were either built under the stretch code or the compliance path utilized by the builder could not be determined.[23] The stretch code was added to the Massachusetts building code in July of 2009 and has been implemented by many municipalities across the state since that time.[24] As of June 24, 2014, 148 municipalities had adopted the stretch code in Massachusetts, accounting for more than one-half of the state's population.[25] Stretch code homes were just beginning to be built at the time of the 2009 IECC inspections and thus represented a very small portion of the overall population. The Team only identified a small number of homes from the 2009 IECC sample that had been constructed under the stretch code and, as a result, did not believe there was sufficient sample to calculate compliance for stretch code homes. Interestingly, Massachusetts adopted the 2012 IECC on July 1, 2014, but the stretch code is still based on amendments from the 2009 IECC; this is something that should be monitored moving forward and accounted for in future code compliance evaluations.

To determine which compliance approach (i.e., prescriptive, UA trade-off, or performance) each audited home used, the evaluation team contacted individual building departments and asked them about the specific sites visited for this study. Some building departments were able to provide compliance information via email and/or telephone, while other building departments had to be visited and the documentation was reviewed onsite. Table 5-1 shows the distribution of how compliance path information was confirmed.

**Table 5-1. Verification of Compliance Path**

| | 2006 IECC Sample | 2009 IECC Sample | Total |
|---|---|---|---|
| *n* | *46* | *90* | *136* |
| Email | 30% | 43% | 39% |
| Telephone | 11% | 7% | 8% |
| In-person visit | 59% | 50% | 53% |

[23] Four homes from the 2009 IECC sample complied with the code under the stretch energy code.
[24] http://www.mass.gov/eopss/consumer-prot-and-bus-lic/license-type/csl/stretch-energy-code-information.html.
[25] http://www.mass.gov/eea/docs/doer/green-communities/grant-program/stretch-code-towns-adoption-by-community-map-and-list.pdf.

# 6. COMPLIANCE RESULTS

This section presents a high-level comparison of the compliance results between the two samples before discussing detailed results for each sample individually.

## 6.1 COMPARISON OF 2006 IECC AND 2009 IECC RESULTS

In order to provide some perspective on the comparison of 2006 IECC and 2009 IECC compliance results, it is important to understand the differences between these codes, specifically in climate zone 5 (where Massachusetts is located). Below is a list of key changes between these two codes, as summarized by the DOE in their publication "Impacts of the 2009 IECC for Residential Buildings at State Level."[26]

- Duct leakage testing is required and must have a post-construction leakage value of less than or equal to 8 CFM25/100 sq. ft. of conditioned floor area.[27] The 2006 IECC required that ducts be sealed, but it did not require testing.
- Fifty percent or more of the lamps in a building must be high-efficacy lamps.[28] There was no efficient lighting requirement in the 2006 IECC.
- The prescriptive insulation requirement for wall insulation increased from R-19 (2006 IECC) to R-20 (2009 IECC), making 2x6 walls more commonplace.
- Improved air sealing language, requiring increased attention to air sealing, along with an option to test the building envelope as opposed to the code inspector visually verifying it.
- Piping for hydronic (boiler) heating systems must be insulated to R-3 or greater. The 2006 IECC required R-2 or greater.
- Controls are required for driveway/snow melting systems. The 2006 IECC did not include a requirement for driveway/snow melting systems.
- Pool covers are required for heated pools. The 2006 IECC did not include a requirement for pool covers.

Figure 6-1 presents the distribution of compliance paths identified for the sites that were included in this study. As shown, more than two-thirds of all homes (67%) used the UA trade-off approach to comply with the energy code. The distribution of compliance paths was very similar between the 2006 IECC and 2009 IECC samples.

[26] http://www.energycodes.gov/sites/default/files/documents/IECC2009_Residential_Nationwide_Analysis.pdf.
[27] CFM25 represents cubic feet per minute at 25 Pascals.
[28] This requirement does not apply to homes that comply via the performance path.

**Figure 6-1. Distribution of Compliance Paths**

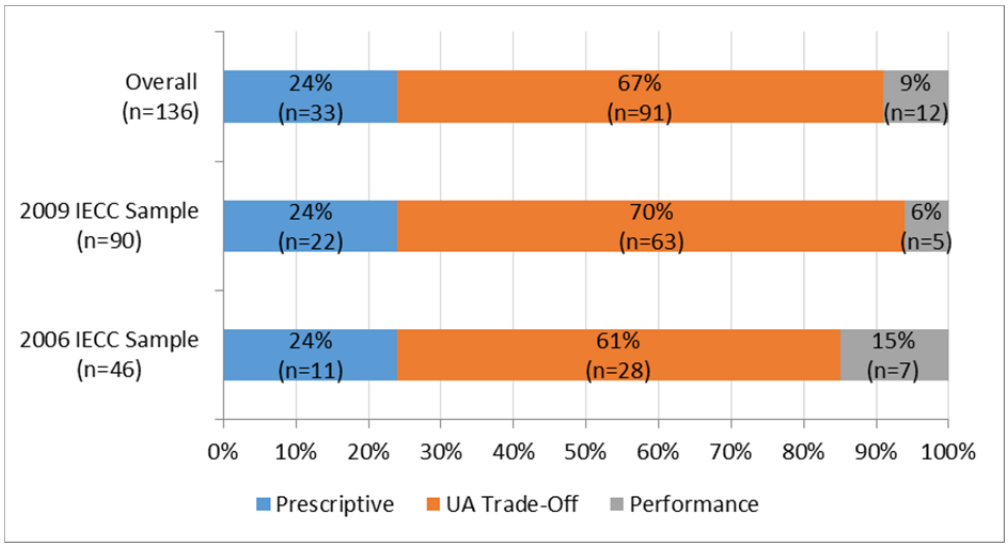
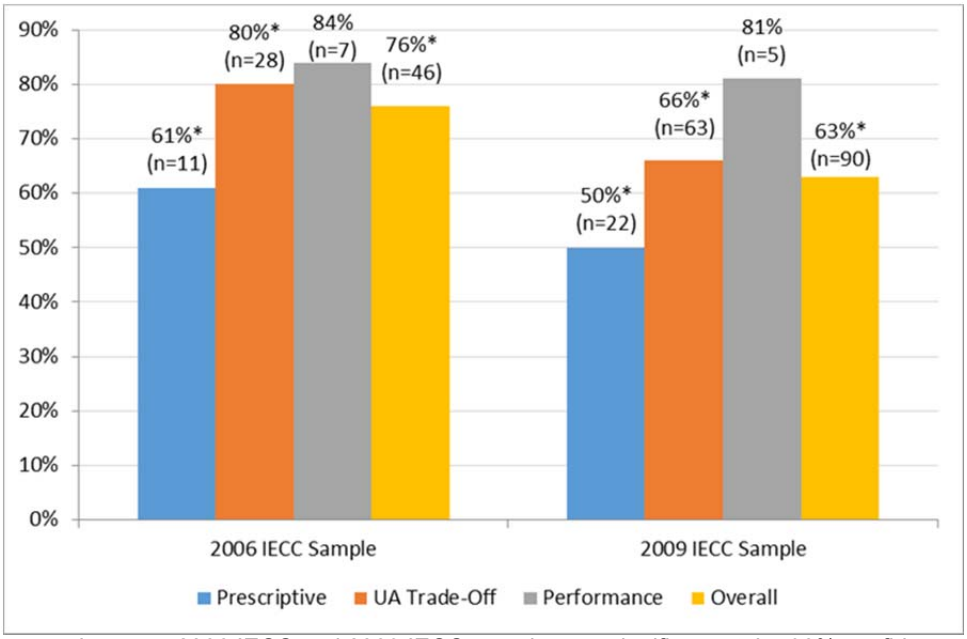



Figure 6-2 shows a comparison of the average compliance levels by compliance path between the 2006 IECC and 2009 IECC samples. Homes built at the end of the 2006 IECC cycle show significantly higher overall compliance (76%) than homes built at the beginning of the 2009 IECC cycle (63%). The same is true when looking at specific compliance paths, where homes built at the end of the 2006 IECC cycle have significantly higher compliance levels than homes built at the beginning of the 2009 IECC cycle under both the prescriptive path (61% vs. 50%, respectively) and the UA trade-off approach (80% vs. 66%, respectively).

**Figure 6-2. Average Compliance Score by Compliance Path**




*Differences between 2006 IECC and 2009 IECC samples are significant at the 90% confidence level.

These results are not particularly surprising given that (1) significant changes took place when the 2009 IECC was implemented (see above) and (2) the homes in the 2006 IECC

sample were built at the end of the code cycle, while the homes in the 2009 IECC sample were built at the beginning of the cycle. One possible reason why homes built at the end of the 2006 IECC cycle show higher compliance is that builders and subcontractors had three years to familiarize themselves with the code before constructing these homes. Builders and subcontractors constructing homes at the beginning of the 2009 IECC cycle were likely just beginning to familiarize themselves with the new code requirements, which may be a cause of lower compliance levels.

Table 6-1 presents a comparison of the percent change in average annual energy consumption (in MMBtu) for 2006 IECC design homes and 2006 IECC reference homes. The design home represents the as-built home (i.e., the house that was inspected) with a few modifications, while the reference home is identical to the as-built home (same square footage, configuration, volume, etc.), but it has the 2006 IECC prescriptive efficiency requirements substituted for the efficiency levels identified during the site visits. As shown, design homes from the 2006 IECC sample have an average annual energy consumption that is 2% greater than the 2006 IECC reference home, while design homes from the 2009 IECC sample have an average annual energy consumption that is 3% lower than the 2006 IECC reference home. Hence, the 2009 IECC sample homes are actually slightly more efficient than the 2006 IECC sample homes, even though the 2009 IECC homes display lower compliance with the applicable energy code. This finding supports the hypothesis that low compliance among the 2009 IECC homes is likely due to the fact that new requirements were implemented with the new energy code and builders were still familiarizing themselves with those requirements, resulting in their display of lower compliance than homes built at the end of a code cycle.

**Table 6-1. Design Home Percent Change from 2006 IECC Reference Home**

| | 2006 IECC Sample | 2009 IECC Sample |
|---|---|---|
| *N* | *46* | *90* |
| Annual Energy Consumption (MMBtu) | 2%* | -3%* |

* Statistically significant difference at the 90% confidence level.

## 6.2 2006 IECC RESULTS

Table 6-2 presents a variety of statistics comparing overall compliance in the 2006 IECC sample against the three individual compliance paths (i.e., prescriptive, UA trade-off, and performance). Please note that the statistics presented for the various columns in Table 6-2 are not necessarily related. For example, the minimum points possible represent the site that had the fewest possible points on the checklist (i.e., the site with the fewest applicable and/or observable requirements), while the minimum points received represent the site that received the fewest points on the checklist. These two data points, the minimum points possible and the minimum points received, could be from two separate homes. As a result, these columns, when compared in the table, do not necessarily compute to the minimum compliance score (i.e., the site that had the lowest compliance score in the sample). The row displaying averages will compute across the columns, but it is the only row that will do so. Compliance percentages range from 36% to 91% overall, illustrating a large range in builders' understanding of the codes. Homes that utilized the performance compliance path show significantly higher compliance than homes that utilized either the UA trade-off or prescriptive compliance paths. Similarly, homes that used the UA trade-off compliance path show significantly higher compliance than homes that used the prescriptive compliance path. These

results indicate that compliance may be more easily achieved using compliance paths with trade-off options, where certain components of the home may fall below code-specified levels as long as the efficiency losses are compensated for elsewhere in the home.

**Table 6-2. 2006 IECC Checklist Compliance Score Results**

| Statistic | Points Possible | Points Received | Compliance |
|---|---|---|---|
| **Overall (n=46)** | | | |
| Minimum | 19 | 10 | 36% |
| Maximum | 61 | 52 | 91% |
| Average | 38 | 29 | 76% |
| Median | 36 | 28 | 82% |
| **UA Trade-Off (n=28)** | | | |
| Minimum | 29 | 20 | 56% |
| Maximum | 61 | 52 | 90% |
| Average | 40 | 32 | 80%[a,b] |
| Median | 36 | 30 | 82% |
| **Prescriptive (n=11)** | | | |
| Minimum | 19 | 10 | 36% |
| Maximum | 37 | 25 | 91% |
| Average | 28 | 17 | 61%[a,c] |
| Median | 28 | 16 | 58% |
| **Performance (n=7)** | | | |
| Minimum | 34 | 25 | 74% |
| Maximum | 52 | 45 | 88% |
| Average | 43 | 36 | 84%[b,c] |
| Median | 40 | 34 | 85% |

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

Table 6-3 presents the 2006 IECC compliance checklist broken down by item group. Items that were not observable were deemed unverifiable. The “Percent Verifiable” column reflects how often the items within a given compliance group were verifiable; the lower the percent verifiable, the less precise the compliance estimate is for an item group. Checklist items such as fenestration (29% verifiable) and air sealing (5%) were difficult to verify post-construction, while floors and walls were verifiable 100% of the time.[29] Compliance percentages exclude checklist items that were either not applicable or not observable. Note that the checklist is populated differently for most shell measures depending on the compliance path that was

[29] The 2006 IECC only allows for air sealing to be assessed based on visual inspection. Because these audits were conducted after the home was occupied, most of the air sealing details could not be inspected.

utilized. If the UA trade-off or performance path was used, then most of the checklist items associated with shell measures were marked as compliant, assuming there was a trade-off taking place elsewhere in the site; this is consistent with the PNNL checklist instructions.

**Table 6-3. 2006 IECC Checklist Compliance Rates by Item Group**

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

Table 6-4 presents the relative influence for each of the item groups in the 2006 IECC checklist. The hypothetical impact was calculated by assuming all checklist items were applicable and observable, which is almost never the case. The actual impact was calculated by assessing the possible points associated with items that were both applicable and verifiable (i.e., included in the actual compliance calculations). The relative influence of the various item groups on overall compliance is pretty evenly distributed when considering the actual impact of each checklist item. Some measures have a very high hypothetical influence, but a substantially lower actual influence on overall compliance because the items are either not applicable most of the time (e.g., foundation walls) or difficult to verify (e.g., fenestration). Other measures, such as floors and walls, have a higher actual impact than they do hypothetical impact. This is due to the fact that these items are applicable in many homes and also are verifiable most of the time.

**Table 6-4. 2006 IECC Checklist Impact by Item Group**

| Compliance Item Group | # of Checklist Items | Total Possible Points | Percent Verifiable | Hypothetical % Impact per Item Group | Actual % Impact per Item Group |
|---|---|---|---|---|---|
| Fenestration | 12 | 33 | 29% | 23% | 14% |
| Ceilings | 4 | 12 | 91% | 8% | 15% |
| Floors | 2 | 6 | 100% | 4% | 16% |
| Walls | 6 | 18 | 100% | 12% | 17% |
| Foundation | 13 | 38 | 70% | 26% | 10% |
| Air Sealing | 4 | 8 | 5% | 6% | 1% |
| HVAC | 10 | 24 | 51% | 17% | 18% |
| Other | 3 | 6 | 67% | 4% | 9% |

## 6.3 2009 IECC RESULTS

Similar to Table 6-2, Table 6-5 presents a variety of statistics comparing overall compliance in the 2009 IECC sample against the individual compliance paths. As is the case with Table 6-2, the statistics presented for the various columns in Table 6-5 are not necessarily related. For example, the minimum points possible represent the site that had the fewest possible points on the checklist (i.e., the site with the fewest applicable and/or observable requirements), while the minimum points received represent the site that received the fewest points on the checklist. These two data points, the minimum points possible and the minimum points received, could be from two separate homes. As a result, these columns, when compared in the table, do not necessarily compute to the minimum compliance score (i.e., the site that had the lowest compliance score in the sample). The row displaying averages will compute across the columns, but it is the only row that will do so. Compliance percentages range from 24% to 89%, which is wider than the range displayed in the 2006 IECC sample. As in the 2006 IECC sample, homes that used the performance path displayed significantly higher compliance than homes that used either the UA trade-off or prescriptive compliance paths. Homes that utilized the UA trade-off approach also displayed significantly higher compliance results than homes that utilized the prescriptive approach. As previously mentioned, these results probably indicate that high levels of compliance are more easily achieved using compliance paths that allow for trade-offs in efficiency levels among various building components.

**Table 6-5. 2009 IECC Checklist Compliance Score Results**

| Statistic | Points Possible | Points Received | Compliance |
|---|---|---|---|
| **Overall (n=90)** | | | |
| Minimum | 29 | 7 | 24% |
| Maximum | 55 | 39 | 89% |
| Average | 40 | 25 | 63% |
| Median | 40 | 25 | 65% |
| **UA Trade-Off (n=63)** | | | |
| Minimum | 29 | 10 | 31% |
| Maximum | 55 | 39 | 89% |
| Average | 41 | 27 | 66%[a,b] |
| Median | 41 | 27 | 68% |
| **Prescriptive (n=22)** | | | |
| Minimum | 29 | 7 | 24% |
| Maximum | 55 | 38 | 74% |
| Average | 37 | 19 | 50%[a,c] |
| Median | 37 | 19 | 49% |
| **Performance (n=5)** | | | |
| Minimum | 37 | 29 | 73% |
| Maximum | 40 | 32 | 87% |
| Average | 38 | 31 | 81%[b,c] |
| Median | 38 | 32 | 81% |

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

Table 6-6 presents the 2009 IECC compliance checklist broken down by item group. Items that were not observable were deemed unverifiable. The “Percent Verifiable” column reflects how often the items within a given compliance group were verifiable; the lower the percent verifiable, the less precise the compliance estimate is for an item group. Air leakage (25%) and “other” (0%) checklist item groups were the least verifiable. The Team used blower door results, when available, to estimate compliance with one of the air leakage items in the checklist. The other two checklist items related to air leakage were not verifiable 100% of the time, as the Team did not inspect them;[30] this is due to the fact that there were no plans to use the data from the 2009 IECC sample inspections for a code compliance analysis. Similarly, the “other” checklist item group is composed of miscellaneous checklist items such as the presence of a compliance certificate or the presence of a heated pool cover. These items are certainly verifiable, even in post-occupancy site visits, but they were not inspected

[30] The 2009 IECC includes mandatory requirements that wood-burning fireplaces be gasketed and that recessed lighting fixtures that are part of the thermal envelope be air-sealed. These two measures were not inspected during the onsite inspections and therefore were not verifiable.

during the site visits since the intention of the inspections at that time was not to assess code compliance. With a few exceptions, the 2009 IECC sample displayed decreases in compliance for nearly all of the checklist item groups when compared to the 2006 IECC sample (Table 6-3). Lighting, a new requirement in the 2009 IECC code, had a surprisingly low compliance rate of 10%. Note, the checklist is populated differently for most shell measures depending on the compliance path that was utilized. If the UA trade-off or performance path was used, then most of the checklist items associated with shell measures were marked as compliant, assuming there was a trade-off taking place elsewhere in the site; this is consistent with the PNNL checklist instructions.

**Table 6-6. 2009 IECC Checklist Compliance Rate by Item Group**

| Compliance Item Group | # of Checklist Items | Percent Verifiable | Compliance | | | |
|---|---|---|---|---|---|---|
| | | | All Homes (n=90) | UA Trade-Off (n=63) | Prescriptive (n=22) | Performance (n=5) |
| Lighting | 1 | 99% | 10% | 8% | 14% | -- |
| Fenestration | 10 | 49% | 100% | 100% | 100% | 100% |
| Ceilings | 5 | 87% | 70% | 71% | 63% | 82% |
| Floors | 2 | 100% | 55% | 58% | 48% | 55% |
| Walls | 6 | 100% | 63% | 67% | 49% | 75% |
| Foundation | 11 | 49% | 79% | 79% | 80% | -- |
| Air Sealing* | 3 | 25% | 92% | 90% | 100% | 100% |
| HVAC | 13 | 36% | 34% | 32% | 34% | 56% |
| Other | 8 | 0% | 0% | 0% | 0% | 0% |

Table 6-7 presents the relative influence for each of the item groups in the 2009 IECC checklist. The hypothetical impact was calculated by assuming that all checklist items were applicable and observable, which is never the case. The actual impact was calculated by assessing the possible points associated with items that were both applicable and verifiable (i.e., included in the actual compliance calculations). As with the 2006 IECC checklist, some measures have a very high hypothetical influence, but a substantially lower actual influence on overall compliance because the items are either not applicable most of the time (e.g., foundation walls) or not verifiable (e.g., other). Other measures, such as floors and walls, have a higher actual impact than they do hypothetical impact. This is due the fact that these items are applicable in many homes and are verifiable most of the time.

**Table 6-7. 2009 IECC Checklist Impact by Item Group**

| Compliance Item Group | # of Checklist Items | Total Possible Points | Percent Verifiable | Hypothetical % Impact per Item Group | Actual % Impact per Item Group |
|---|---|---|---|---|---|
| Lighting | 1 | 3 | 99% | 2% | 7% |
| Fenestration | 10 | 30 | 49% | 19% | 14% |
| Ceilings | 5 | 15 | 87% | 10% | 20% |
| Floors | 2 | 6 | 100% | 4% | 13% |
| Walls | 6 | 18 | 100% | 12% | 15% |
| Foundation | 11 | 32 | 49% | 21% | 4% |
| Air Sealing | 3 | 7 | 25% | 5% | 5% |
| HVAC | 13 | 28 | 36% | 18% | 20% |
| Other | 8 | 15 | 0% | 10% | 0% |

# APPENDIX A: 2006 AND 2009 IECC CHECKLISTS

This appendix provides embedded PDFs of the 2006 and 2009 IECC checklists. Double click on the embedded image and the PDF version of the checklists will open.

**2006 IECC Checklist**

2006 IECC Checklist

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**2009 IECC Checklist**

2009 IECC checklist

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