2015 Single-Family Stretch Code Update Compliance and Potential-Final Report

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SUBMITTED TO:
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Executive Summary

Beginning in January of 2017, the Massachusetts stretch code references the 2015 International Energy Conservation Code (IECC) rather than the 2009 IECC that it was previously based on.[1] The new stretch code requirements are being referred to as the **2015 Stretch Code Update**. This study calculates projected statewide compliance estimates for stretch code homes and assesses the projected potential savings from compliance enhancement from single family homes that will be built under the 2015 Stretch Code Update. *Please note, the homes used for the analysis in this report were built under the **previous** stretch code requirements that were based on the 2009 IECC. This assessment is meant to provide insight into what the possibility for maximum compliance enhancement potential might be under the new stretch code requirements given current building practices.*

Study Objectives and Rationale

The objective of this study is to assess whether there are significant savings opportunities from compliance enhancement efforts in stretch code municipalities given the recent adoption of the 2015 Stretch Code Update and the associated stringency of the efficiency requirements. The Program Administrators (PAs) and Energy Efficiency Advisory Council (EEAC) determined that this study was an opportunity to conduct a simplified analysis, based on pre-existing data collection, to determine if projected stretch code compliance and the associated compliance enhancement savings potential justify further evaluation research.

Summary of Results

Using the MA-REC (Massachusetts Residential Evaluation Contract) compliance methodology (see Appendix A for details), statewide compliance is 96% compared to the previous requirements and is projected to be 90% compared to the 2015 Stretch Code update (Table 1). Throughout this report results from previous studies are included for reference and are shown in table cells with gold backgrounds.

Table 1: Projected MA-REC Compliance (As-Built)

Code	Program	Non-Program	Statewide
2015 Stretch Code Update	92%	83%	90%
Stretch Code 2009 IECC	97%	93%	96%

[1] http://www.mass.gov/eopss/consumer-prot-and-bus-lic/license-type/buildings/amendments-to-780-cmr-effective-august-12-2016.html

In addition to the MA-REC methodology, the Team investigated compliance based on HERS score requirements. The 2015 Stretch Code Update requires a HERS score of 55, a substantial change from the previous stretch code that required a HERS score of 65 or 70 depending on the size of the home.[2] Table 2 shows that, statewide, only 20% of stretch code homes built under the previous stretch code requirements are projected to meet the 2015 Stretch Code Update HERS score requirement (24% of program and 7% of non-program homes). This represents a 69-point drop in compliance compared to the fraction of homes that comply with the previous version of the stretch code (89%). It should be noted that the definition of the HERS score was recently revised and, as discussed in Section 2.1, these changes are known to increase HERS scores. This has an impact on the projected compliance estimates and makes it more difficult for homes to meet the new HERS score requirements.

The difference in projected compliance scores between the MA-REC approach and the HERS score approach are driven by the difference in methodologies. Under the HERS score methodology, compliance assessment homes are considered non-compliant if they do not meet the HERS score requirement; the level of non-compliance does not influence the projected compliance score. For example, homes that fall just below the HERS score requirement (e.g., a HERS score of 56) and homes that fall well below the HERS score requirement (e.g., a HERS score of 75) are assigned the same compliance score of 0%. One the other hand, the MA-REC approach applies partial credit for compliance and therefore homes that fall just short of compliance are attributed a relatively high compliance rate while homes that fall well below the compliance requirements are assigned a low compliance rate.

Table 2: Projected Stretch Code 2015 HERS Score Compliance (As-Built)

Condition	Program	Non-Prog.	Statewide
2015 Stretch Code Update	24%	7%	20%
Stretch Code 2009 IECC	99%	56%	89%

To assess the projected compliance enhancement potential for stretch code homes that will be built under the 2015 Stretch Code Update, the Team used three different methodologies. Details on these methodologies can be found in Section 2. These projections should be considered as maximum compliance enhancement estimates as the homes included in this analysis were built under the previous stretch code requirements; it is unlikely that homes built under the 2015 Stretch Code Update will decrease in efficiency and therefore the potential savings estimates are unlikely to increase. Table 3 shows that projected compliance enhancement ranges from 13% to 34% statewide depending on the methodology that is used. This represents a substantial increase in potential compared to

[2] The former stretch code required 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).

the potential for stretch code homes built under the previous requirements (5%) using the MA-REC methodology.

Please note, it is expected that non-compliance levels and compliance enhancement potential may not align perfectly due to various interactions. Under the MA-REC compliance system, building component point weighting is based on mean energy consumption of the sample in question while the potential savings calculations are based on each of the sampled homes and do not account for the average characteristics of the sample. In the HERS score-based code compliance assessment, compliance is binary (i.e. homes are either 100% compliant or 0% compliant) since the building code does not allow for partial compliance. The potential savings, however, do award partial credit. Therefore, the congruence of stretch code compliance and potential savings levels is dependent on the distribution of sample home HERS scores. For example, some homes that barely miss the compliance threshold should have minimal potential savings available while other homes that fall far below the compliance threshold may have large potential savings.

Table 3: Projected Compliance Enhancement Potential

Model	Program	Non-Program	Statewide
MA-REC	11%	25%	14%
RESNET Ratio	11%	20%	13%
Sample Ratio	28%	53%	34%
Stretch Code 2009 IECC MA-REC	4%	9%	5%

CONCLUSIONS AND RECOMMENDATIONS

Below are lists of conclusions and recommendations based on the results of this study.

Conclusions

- The 2015 Stretch Code Update resulted in a significant increase in efficiency requirements for stretch code homes. While this report is based on homes that were built under the ***previous*** stretch code requirements, we project that the 2015 Stretch Code Update will result in decreased compliance statewide for stretch code homes and an increase in the potential for compliance enhancement.
- Assuming building practices remain the same, statewide compliance using the MA-REC methodology is projected to be 90% under the 2015 Stretch Code Update requirements. This compares to a statewide compliance rate of 96% under the previous stretch code requirements.
- Assuming building practices remain the same, statewide compliance with the 2015 Stretch Code Update HERS score requirement of 55 is projected to be only 20%. This compares to a statewide compliance rate of 89% under the previous stretch code requirements.

- Maximum projected potential energy savings from compliance enhancement are 14% statewide using the MA-REC methodology. This compares to 5% under the previous stretch code requirements.
- Maximum projected potential energy savings from compliance enhancement range from 13% to 34% using methods that compare HERS scores to energy usage.

Recommendations

- **The PAs should continue to provide trainings and support for compliance enhancement in stretch code municipalities.** The findings of this study suggest that the 2015 Stretch Code Update requirements are likely to result in decreased compliance in stretch code municipalities resulting in potential savings from compliance enhancement that may be significant.
- **The PAs should measure compliance with homes that were permitted and built under the 2015 Stretch Code Update.** As previously mentioned, this study assesses projected compliance rates and compliance enhancement savings opportunities based on data from homes built under the previous stretch code requirements. As a result, these findings are preliminary projections and do not necessarily reflect the building practices that will take place under the 2015 Stretch Code Update. To verify these projections a supplemental study is recommended that focuses on homes built under the new stretch code requirements.

1 Section 1 Introduction & Background

Beginning in January of 2017, the Massachusetts stretch code references the 2015 International Energy Conservation Code (IECC) rather than the 2009 IECC that it was previously based on.[3] The new stretch code requirements are being referred to as the **2015 Stretch Code Update**. As part of the recent single-family compliance/baseline study, [4] NMR assessed stretch code compliance under the previous stretch code requirements that were based on the 2009 IECC. This assessment was primarily conducted using the new MA-REC (Massachusetts Residential Evaluation Contract) compliance methodology (detailed in Appendix A). As part of that study, the potential savings associated with stretch code compliance enhancement were calculated by assuming full compliance with prescriptive path of the 2009 IECC code.

This study uses the MA-REC methodology, along with a comparison to the 2015 Stretch Code Update Home Energy Rating Score (HERS) requirements, to calculate projected statewide compliance estimates for homes that will be built under the 2015 stretch code. In addition, this study estimates the maximum potential savings from compliance enhancement for homes that will be built under the 2015 Stretch Code Update.

*Please note, the homes used for the analysis in this report were built under the **previous** stretch code requirements that were based on the 2009 IECC. This assessment is meant to provide insight into what the possibility for maximum compliance enhancement potential might be under the new stretch code requirements given current building practices.*

1.1 Purpose of the Study

The objective of this study is to assess whether there are significant savings opportunities from compliance enhancement efforts in stretch code municipalities given the recent adoption of the 2015 Stretch Code Update and the associated stringency of the efficiency requirements. The Program Administrators (PAs) and Energy Efficiency Advisory Council (EEAC) determined that this study was an opportunity to conduct a simplified analysis, based on pre-existing data collection, to determine if projected stretch code compliance and the associated compliance enhancement savings potential justify further evaluation research.

1.2 Research Questions

This study seeks to answer the following research questions:

- What is the estimated savings potential of stretch code homes that will be built under the 2015 Stretch Code Update?

[3] http://www.mass.gov/eopss/consumer-prot-and-bus-lic/license-type/buildings/amendments-to-780-cmr-effective-august-12-2016.html
[4] http://ma-eeac.org/wordpress/wp-content/uploads/Single-Family-Code-Compliance-Baseline-Study-Volume-4.pdf

    - How do the estimated potential savings vary between program and non-program homes?
- What is the projected compliance rate of stretch code homes that will be built under the 2015 Stretch Code Update?
    - How do the projected compliance rates vary between program and non-program homes?
- How does projected compliance vary when using the MA-REC compliance methodology vs. assessing compliance with the new HERS score requirements?

1.3 Changes in Stretch Code Requirements

As previously mentioned, the previous stretch code was based on the 2009 IECC. Specifically, the code required that homes built in stretch code communities meet the mandatory requirements of the 2009 IECC and achieve a HERS score of 65 or 70, depending on the size of the home.[5] The 2015 Stretch Code Update requires homes to comply with the 2015 IECC mandatory requirements and achieve a HERS score of 55. The 2015 Stretch Code Update allows for a slightly less efficient building (i.e., a higher HERS score of 60-67) if qualifying renewable energy systems are installed. The increase in HERS score requirements for installing renewable energy systems are referred to as *credits* in the remainder of this report. Table 4 and Table 5 detail the renewable energy credits available under the 2015 Stretch Code Update along with the new HERS score requirements with and without renewable energy system credits.

Table 4: 2015 Stretch Code Renewable Energy System Credits

Abbrev.	Renewable System	Credits
DHW	Solar hot water	2
PV	>2.5kW Photovoltaics	5[6]
RPH	Renewable primary heating	5

Table 5: Maximum HERS Ratings with Onsite Renewable Energy Systems

Stretch Code HERS Req. with Renewables	HERS Index	Credits
None	55	0
PV or RPH	60	5
DHW + PV or RPH	62	2 + 5
DHW + PV and RPH	67	5 + 2 + 5

[5] The former stretch code required 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).
[6] Based on NREL's PV Watts Calculator http://pvwatts.nrel.gov/pvwatts.php using TMY3 data for Worcester, MA a minimally qualifying PV array reduces the HERS rating for a typical stretch code home by 10.6 HERS score points, and an average sized array reduces a home's rating by 30.6 HERS score points.

Table 6 summarizes the prescriptive code requirements for the 2009 IECC and 2015 IECC. While the stretch code is a performance-based code that is meant to exceed the base code, the mandatory requirements of the base code still apply to stretch code homes. Measures that are listed as *path dependent* do not have to meet the prescriptive efficiency requirements as they can be used as a trade-off with other measures in the home. These prescriptive values are also the foundation for the MA-REC compliance methodology that is used in this report.

Table 6: Building Code Comparison*

Building System	2015 IECC Requirement	2009 IECC	2015 IECC
Above-grade wall U-factor	*Path dependent*	*0.057*	*0.06*[7]
Window U-factor	Path dependent	0.35	0.30‡
Skylight U-factor	Path dependent	0.60	0.55
Ceiling U-factor	Path dependent	0.03	0.026
Air leakage (ACH50)	Mandatory	7	3
Duct leakage to the outside (CFM25/ft^2)	Mandatory	0.08	N/A
Total duct leakage (CFM25/ft^2)§	Mandatory	0.12	0.04
Duct insulation Supply / Other	*Path dependent*	*8 / 6*	*8 / 6*
Frame floor U-factor	*Path dependent*	*0.033*	*0.033*
Efficient lighting (% of high efficacy fixtures)	Mandatory	50%	75%
Foundation wall U-factor	Path dependent	0.059	0.05
Slab R-value, Non-radiant / Radiant	*Path dependent*	*10 / 15*	*10 / 15*

* Italics denote measures that have not undergone changes in requirements.

‡ MA-specific amendment.

§ Testing is mandatory, but the specific leakage value is a prescriptive requirement.

[7] "The intent of these changes is not to alter the stringency of the code, but rectify the conversion from R-values to U-values." https://oaktrust.library.tamu.edu/bitstream/handle/1969.1/154754/ESL-TR-14-08-01.pdf?sequence=1&isAllowed=y#page=8

2 Section 2 Methodology

The Team utilized two separate methodologies to develop compliance projections for homes that will be built under the 2015 Stretch Code Update. The Team also assessed the potential savings associated with compliance enhancement using a few different approaches.

First, the Team applied the MA-REC methodology that was developed as part of the most recent single-family compliance/baseline study. This methodology was used to calculate compliance and to assess potential savings from compliance enhancement; the details associated with this methodology can be found in Appendix A. *Please note that for the purposes of this study, the sample of stretch code homes that were built to the previous 2009 IECC stretch code requirements were compared to the 2015 IECC requirements; the previous study compared these stretch code homes to the 2009 IECC requirements.*

An alternative approach to assessing compliance with stretch code homes is to simply determine how many homes meet the current stretch code HERS score requirement of 55. Stretch code compliance enhancement potential can also be calculated by comparing how far away from the current HERS score requirement the homes in the sample are.

2.1 HERS & REM/RATE UPDATE

At the same time the 2015 Stretch Code Update went into effect, several changes to the HERS score algorithm and the software the Team uses to calculate these scores (REM/Rate) also occurred. As a part of ANSI standardization, RESNET, the authority responsible for the HERS score system, instituted changes to weather data, ventilation, and the default solar heat gain constant for windows, among others. It is estimated that these adjustments increase typical home scores by one to three points. They also made accommodations for efficient domestic hot water (DHW) systems[8] that could decrease scores by as much as three points. In addition, sanity-checks were instituted to restrict the range of some algorithm inputs. RESNET reports that these checks may increase the scores of some homes by seven points on average.[9]

Version 15.3 of the REM/Rate software used in this analysis also received several other bug fixes and enhancements besides the ANSI-mandated changes described above since the release of version 14.6.2, which was used in the last report.[10] One notable change is the use of localized wind speed data for air leakage calculations.

The Team expects that the net effect of all these adjustments is to increase the difficulty of complying with the 2015 Stretch Code Update HERS score requirements.

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[8] Efficient DHW systems include pipes insulated to R-3 or greater, low-flow (≤2gpm) faucets and shower heads, drain water heat recovery systems, and hot water recirculation controls.

[9] http://www.resnet.us/blog/wp-content/uploads/2015/05/Upcoming-Changes-to-the-HERS-Index-and-Potential-Impact-on-HERS-Index-Scores.pdf

[10] http://www.remrate.com/home/versionhistory

2.2 SAMPLE

Statewide results were calculated using 2015 Residential New Construction (RNC) program homes and non-program homes from the 2015-16 Single-Family Compliance/Baseline study.[4] The Team used the estimated program penetration rate of 77% that was identified in that report to weight results to the full population of single-family stretch code homes. Program home results were weighted by 77% while the non-program results were weighted by 23%. *Again, note that these homes were built under the previous version of the stretch code based upon 2009 IECC.*

2.3 OUTLIERS

We thought it prudent to examine the data at the site level to see if recent changes to REM/Rate (as discussed above) led to drastic changes in model outputs between v14.6.2 and v15.3. Through the course of examination, it became clear that some sites were adversely affected by the changes (e.g. a 19,600% change in energy consumption of a building system component).

Since we did not want the presence of these sites in the data to skew the results, we identified and employed an objective method for identifying outliers, namely the Generalized Extreme Studentized Deviate Test for Multiple Outliers, also known as the Grubbs' test. The Grubbs' test is a statistical method for identifying outliers based on confidence levels and standard deviations from the mean. The test was employed as an objective mechanism for data cleaning; if the change in measure-level outputs between REM/Rate versions was flagged as an outlier then the measure for that home was marked as a missing value for the subsequent analysis. Consequently, the sample size for each measure is different as noted in Table 10.

Ultimately, ten percent (188 homes) of the 1,905 single-family stretch code homes from the 2015 RNC program were excluded from the final sample due to REM/Rate processing problems or being significant outliers in the sample.[11]

2.4 HERS SCORE COMPLIANCE AND ALTERNATIVE POTENTIAL SAVINGS METHODOLOGIES

The Team developed compliance scores at the statewide level by comparing the HERS scores of program participants and those of non-participants (from the baseline study) to the 2015 Stretch Code Update HERS score requirement of 55. If a home achieved a HERS score of 55 or lower, then the home is considered compliant; if a home achieved a score higher than 55 then the home is considered non-compliant.

[11] All 74 program homes in Hopkinton were identified as considerable outliers for multiple dimensions of the compliance analysis. We believe this is primarily due to changes in the weather data file and the implementation of the new scoring algorithm in REM/Rate.

2.4.1 Potential Savings Methodologies

Given the fact that the stretch code requires specific HERS scores, the Team sought to identify methodologies that could detail the potential energy savings associated with moving from one HERS score to another. The sections below detail two separate approaches that the Team investigated to assess the potential savings from increasing compliance in stretch code homes.

The Team did not account for the use of renewable energy system credits when assessing compliance with the HERS score requirements. Therefore, the HERS-based potential savings presented in this report represent a maximum saving potential, and the actual potential may be lower if builders or homeowners elect to pursue renewables as another means of improving a home's score *e.g;* for marketing purposes, or due to lower costs.[12] However, less than 2% of modeled homes have qualifying renewable systems. In addition, it is clear from Figure 1, a scatterplot of HERS scores versus the Massacusetts code amendment renewable energy systems credits installed in the modeled homes, that credited systems are most often installed in homes that are already high-performing. Therefore, it is not unreasonable to assume that renewable credits will remain the exception rather than the rule when it comes to increasing compliance with the stretch code.

Figure 1: MA HERS Credit Distribution of Sample Homes

For additional context, Table 7 provides a break-down of observed renewable energy system types by program status. Note that due to the scale of the figures, results are given per mille (thousandths) rather than percent (hundredths).

Table 7: Creditable Renewables Systems Distribution in Sample Homes

Renewables	Program	Non-Program	Statewide
DHW	3.5‰	0.0‰	3.4‰
PV	11.1‰	93.0‰	13.1‰
PV & DHW	0.6‰	0.0‰	0.6‰
PV & RPH	0.6‰	0.0‰	0.6‰
RPH	4.1‰	46.5‰	5.1‰

[12] Particularly photovoltaics, via Solar Renewable Energy Certificates (SRECs) or power purchase agreements.

2.4.1.1 RESNET Ratio

RESNET specifies the relationship between the HERS score and energy use in the 2013 Home Energy Rating System Standards.[13] The standards state that:

> *§303.2.1 …Each integer value on the scale shall represent a 1% change in the total energy use of the Rated home relative to the total energy use of the Reference home….*

Using this ratio, a one percent change in total energy use for every one-point change in HERS score, the Team could calculate the potential energy savings associated with moving from one HERS score to another for a single home. The actual calculations used to determine RESNET-savings potentials are based on the average energy use intensity (EUI) of sampled homes, that is, the energy use per square foot.

2.4.1.2 Sample Ratio

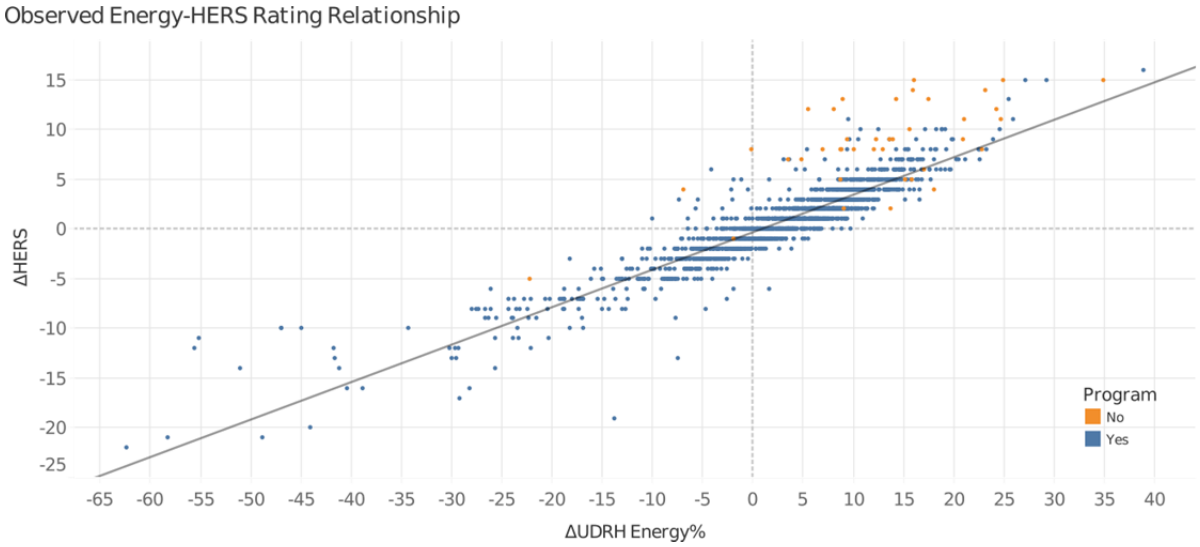
The Team assessed the accuracy of the RESNET ratio by comparing how REM/Rate modeled energy use changes when HERS scores change among the sampled stretch code homes (both program and non-program). Specifically, for each home, the Team compared the as-built home to a User Defined Reference Home (UDRH) based on the 2015 IECC prescriptive requirements. This resulted in four data points for each of the sampled homes:

1. The as-built energy use
2. The as-built HERS score
3. The energy use if each home was built to the 2015 IECC prescriptive requirements (referred to as the reference home)
4. The HERS score if each home was built to the 2015 IECC prescriptive requirements

In Figure 2 below, the percent change in energy use between the as-built and UDRH reference homes is plotted against the corresponding change in HERS scores for each of the sites in this study. The Y-axis represents the difference in HERS scores (the difference between #2 and #4 above), while the X-axis represents the percentage change in energy use (based on the difference between #1 and #3 above). The trend line indicates a relationship of 1:2.65%, with R^2=0.828, rather than the 1:1% RESNET definition. Therefore, the sampled stretch code homes suggest that the RESNET ratio may be overly conservative, given the observed relationship of a 2.65% change in energy use for every one-point change in HERS score.

[13] http://www.resnet.us/standards/RESNET_Mortgage_Industry_National_HERS_Standards.pdf#page=28

Figure 2: Comparison of Change in HERS Score vs. Change in Energy Use



3 Section 3 Results

This section presents the compliance results and potential savings assessment associated with the MA-REC methodology and the alternative methodologies that are described in Section 2. Throughout this section, results from the most recent single-family compliance/baseline study are highlighted in gold.

3.1 Compliance Rates

Table 8 presents the projected MA-REC compliance rates that were calculated as part of this assessment along with the scores that were calculated as part of the previous single-family compliance/baseline study. As shown, under the 2015 Stretch Code Update, compliance is projected to be 90% statewide; 92% for program homes and 83% for non-program homes. In other words, the level of statewide compliance for homes to be built under the stretch code is projected to fall by 6 percentage points versus current stretch code compliance levels. Additionally, non-program homes are projected to reduce their overall compliance levels more than program homes.

Table 8: Projected MA-REC Compliance

Code	Program	Non-Program	Statewide
2015 Stretch Code Update	92%	83%	90%
Stretch Code 2009 IECC	97%	93%	96%

The mean as-built HERS rating is 60 for program homes and 72 for non-program homes using the newest version of REM/Rate. Table 9 shows which fraction of homes would pass the 2015 Stretch Code Update HERS score threshold under various conditions. The first row (No Additional Renewables) lists as-built homes that pass the current HERS score requirement of 55. As shown, only 20% of stretch code homes statewide meet the 2015 Stretch Code Update requirement (24% and 7% for program homes and non-program homes, respectively). This represents a 69 point drop in compliance compared to the fraction of homes that comply with the previous version of the stretch code (89%). It should be noted that the definition of the HERS score was recently revised and, as discussed in section 2.1, the changes are known to increase HERS scores. This has an impact on the projected compliance estimates and makes it more difficult for homes to meet the new HERS score requirements. The remaining rows of the table show how many homes might be expected to pass if they were to install different combinations of renewable energy systems.

The difference in projected compliance scores between the MA-REC approach and the HERS score approach are driven by the difference in methodologies. Under the HERS score compliance assessment, homes are considered non-compliant if they do not meet the HERS score requirement; the level of non-compliance does not influence the projected compliance score. For example, homes that fall just below the HERS score requirement

(e.g., a HERS score of 56) and homes that fall well below the HERS score requirement (e.g., a HERS score of 75) are assigned the same compliance score of 0%. One the other hand, the MA-REC approach applies partial credit for compliance and therefore homes that fall just short of compliance are attributed a relatively high compliance rate while homes that fall well below the compliance requirements are assigned a low compliance rate.

Table 9: Projected Stretch Code 2015 As-Built Compliance with Renewables Credits

Condition	Credit	Program	Non-Prog.	Statewide
No Additional Renewables	0	24%	7%	20%
DHW	2	32%	7%	26%
PV or RPH	5	47%	12%	39%
DHW + PV or RPH	7	61%	16%	51%
PV and RPH	10	76%	23%	64%
DHW + PV and RPH	12	85%	30%	73%
Stretch Code 2009 IECC	N/A	99%	56%	89%

Based on the mean HERS scores it appears there may be room for overall code compliance enhancement in stretch code communities given the increase in requirements of the 2015 Stretch Code Update. Program homes are, on average, about five HERS points away from compliance. Non-program homes show much more room for improvement as they are an average of 16 HERS points away from meeting the new maximum HERS score requirement of 55.

3.2 Potential Savings from Compliance Enhancement

This section details the projected maximum gross potential savings associated with increasing compliance in stretch code communities. These projections are maximum compliance enhancement estimates as the homes included in this analysis were built under the previous stretch code requirements; it is unlikely that homes built under the 2015 Stretch Code Update will decrease in efficiency and therefore the potential savings estimates are unlikely to increase.

Please note, it is expected that non-compliance levels and compliance enhancement potential may not align perfectly due to various interactions. Under the MA-REC compliance system, building component point weighting is based on mean energy consumption of the sample in question while the potential savings calculations are based on each of the sampled homes and do not account for the average characteristics of the sample. In the HERS score-based code compliance assessment, compliance is binary (i.e. homes are either 100% compliant or 0% compliant) since the building code does not allow for partial compliance. The potential savings, however, do award partial credit. Therefore, the congruence of stretch code compliance and potential savings levels is dependent on the

distribution of sample home HERS scores. For example, some homes that barely miss the compliance threshold should have minimal potential savings available while other homes that fall far below the compliance threshold may have large potential savings.

3.2.1 MA-REC Compliance Potential Assessment

Overall, using the MA-REC methodology, the statewide savings potential is projected to change from 5% (as identified in the previous study) for homes built under the previous stretch code to 14% for homes built under the 2015 Stretch Code Update. Table 10 outlines the measure level savings potentials for program and non-program homes, as well as the weighted statewide potential savings. The far-right column of the table shows the statewide savings potential under the previous stretch code requirements. Measures are sorted in order of impact *i.e;* savings potential × non-compliance rate. The two measures with greatest savings potential, duct leakage and air leakage, are also the two measures for which requirements have changed the most between the 2009 IECC and 2015 IECC. [14]

[14] Excluding the 50% increase in efficient lighting requirement, however its impact is negligible given the high compliance rate among program homes in Massachusetts.

Table 10: Projected Gross Technical Potential Savings

(% of As-Built Consumption)

Building System	Requirement	Program		Non-Program		Statewide	
		Potential	n	Potential	n	Potential	SC09
Duct Leakage*	Mandatory	3.4%	1,163	6.1%	37	4.0%	1%
Air Leakage*	Mandatory	2.6%	826	4.5%	29	3.0%	0%
Ceilings*	Path dependent	1.3%	1,277	2.1%	37	1.5%	0%
Frame Floors	Path dependent	1.5%	1,358	1.2%	32	1.4%	1%
Walls*	Path dependent	1.0%	788	1.7%	37	1.2%	1%
Windows*	Path dependent	0.2%	779	3.7%	38	1.0%	0%
Foundation Walls	Path dependent	1.0%	676	0.9%	16	1.0%	0%
Lighting*	Mandatory	0.1%	32	4.4%	37	1.1%	1%
Slabs	Path dependent	0.2%	475	0.2%	16	0.2%	0%
TOTAL		11.3%	*1,717*	24.8%	*43*	14.4%	5%

*Statistically significant difference between program and non-program homes at the 90% confidence level.

3.2.2 Potential Savings Results Using HERS Score versus Energy Use Ratios

This section presents the potential energy savings from stretch code compliance using multiple models based on relationships between HERS score and home energy use. As previously noted in section 2.4.1 Potential Savings Methodologies, these models assume all stretch code compliant homes achieve a HERS score of 55 without credits for renewable energy systems. As shown, projected statewide compliance enhancement potential ranges from 13% to 34% depending on the HERS score versus home energy use methodology that is used.

Table 11: Projected HERS-derived Compliance Savings Potentials
(% of As-Built Consumption)

Model	Program	Non-Program	Statewide
RESNET Ratio[15]	11%	20%	13%
Sample Ratio	28%	53%	34%

A HERS-score based approach is inherently tied to a home-level analysis and therefore this methodology does not allow for the measure-level compliance assessment that is included in the MA-REC methodology.

[15] RESNET Potentials do not match the change in average HERS score required to meet stretch code as one might expect. When calculating the mean HERS score very high performing homes can offset very low-performing homes. By contrast, the energy savings potential of all stretch code compliant homes is 0, regardless of how well it performs, yielding a higher average RESNET potential than expected. There is also a weak relationship between HERS score and energy use which further increases this discrepancy; the **average** energy consumption of homes with a given HERS score increases by 6% for each HERS point, R^2=0.352.

4 Section 4 Conclusions & Recommendations

Below are lists of conclusions and recommendations based on the results of this study. It is important to keep in mind that this study is based on homes that were built under the previous stretch code requirements even though they are being compared to the 2015 Stretch Code Update. The purpose of this study is to assess whether there might be significant savings opportunities from compliance enhancement efforts in stretch code municipalities given the recent adoption of the 2015 Stretch Code Update and the associated stringency of the efficiency requirements.

Conclusions

- The 2015 Stretch Code Update resulted in a significant increase in efficiency requirements for stretch code homes. While this report is based on homes that were built under the ***previous*** stretch code requirements, we project that the 2015 Stretch Code Update will result in decreased compliance statewide for stretch code homes and an increase in the potential for compliance enhancement.
- Assuming building practices remain the same, statewide compliance using the MA-REC methodology is projected to be 90% under the 2015 Stretch Code Update requirements. This compares to a statewide compliance rate of 96% under the previous stretch code requirements.
- Assuming building practices remain the same, statewide compliance with the 2015 Stretch Code Update HERS score requirement of 55 is projected to be only 20%. This compares to a statewide compliance rate of 89% under the previous stretch code requirements.
- Maximum projected potential energy savings from compliance enhancement are 14% statewide using the MA-REC methodology. This compares to 5% under the previous stretch code requirements.
- Maximum projected potential energy savings from compliance enhancement range from 13% to 34% using methods that compare HERS scores to energy usage.

Recommendations

- **The PAs should continue to provide trainings and support for compliance enhancement in stretch code municipalities.** The findings of this study suggest that the 2015 Stretch Code Update requirements are likely to result in decreased compliance in stretch code municipalities resulting in potential savings from compliance enhancement that may be significant.
- **The PAs should measure compliance with homes that were permitted and built under the 2015 Stretch Code Update.** As previously mentioned, this study assesses projected compliance rates and compliance enhancement savings opportunities based on data from homes built under the previous stretch code requirements. As a result, these findings are preliminary projections and do not necessarily reflect the building practices that will take place under the 2015 Stretch

Code Update. To verify these projections a supplemental study is recommended that focuses on homes built under the new stretch code requirements.

Appendix A MA-REC Compliance Methodology

This appendix details the methodology that is used to develop compliance scores using the MA-REC compliance approach. This approach was developed as part of the most recent single-family compliance/baseline study. The language below is from the previous study and as a result references codes that may not have been considered as part of this report. ***Please note that for the purposes of this study the sample of stretch code homes was compared to the 2015 IECC requirements; the previous study compared stretch code homes to the 2009 IECC requirements.***

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. Thus, 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.[16] The consumption estimates of individual measures are compared to the overall estimated consumption for a sample of homes 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.[17]

The point system is developed on a ten-point scale where the most impactful measure (in terms of relative estimated energy consumption) receives an achievable score of ten points.

[16] 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.
[17] 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.

Other measures are compared to the most important measure to develop an achievable point value between zero and ten points. The following formula provides an example of how the total possible points for each measure is 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.[18] 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:

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

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

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

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

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

has a higher consumption than the code-built model because 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:

$$Points_{Scored} = \begin{cases} Points_{Possible} \times (1 + PC_{Base})\ if\ PC_{Base} < 0 \\ Points_{Possible}\ if\ PC_{Base} \geq 0 \end{cases}$$

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.

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

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 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 normalizes scores from 0% to 100% to facilitate cross code comparisons.