The Untapped Potential in Code Compliance: A Study in Residential New Construction

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ABSTRACT

As various states adopt more stringent energy codes for new buildings such as IECC 2009, compliance becomes increasingly important, and the savings to be realized from enhanced code compliance can be sizeable. This paper presents the results of a study estimating the maximum potential savings from enhanced compliance with the IECC 2009 code for residential new construction in Massachusetts. Four measures were studied: wall insulation, basement insulation, proper sealing of ducts in unconditioned spaces, and meeting the fifty percent high efficacy lamp requirement. Generating the savings numbers associated with enhanced compliance is a necessary step in spurring efforts by energy efficiency Program Administrators (PAs) to promote code compliance, primarily through trainings of builders, subcontractors, and code officials, and as a basis to claim some credit for the resulting savings.

The analysis estimated the baseline rates of compliance for the four measures for homes completed in three years: 2011, 2012, and 2013; that is, what compliance could be expected without additional efforts by the PAs and others. The anticipated baseline compliance rates were developed through a review of code compliance studies across the nation as well as interviews with local building code experts. The savings potential estimates also rely on the number of single and multifamily units expected to be completed in the years under study, excluding the units coming in under the state's ENERGY STAR Homes Program.

The analyses done to date point to sizeable potential benefits from enhanced residential code compliance—even under sensitivity analyses that used lower housing forecasts and higher rates of assumed baseline compliance.

Introduction

The Massachusetts PAs are poised to play an increasingly important role in promoting energy code compliance. First, following the adoption of the Green Communities Act of 2008, the state now mandates that all building permits drawn as of July 1, 2010 comply with the IECC 2009 code. The state building code is due to be updated every three years, with the latest IECC code adopted by the state within 12 months of its release. Compliance has gained prominence as the American Recovery and Reinvestment Act (ARRA) calls for 90% compliance with the new energy codes within eight years as a condition for state energy program funding. The PAs have promoted code compliance primarily through trainings of builders, subcontractors, and code officials. In late 2010, estimates of the *maximum potential* savings for the years 2011, 2012, and 2013 that may be achieved through compliance enhancement efforts were developed for

four measures in order to provide needed guidance to the PAs on the implementation and evaluation costs that may be justified. The potential savings presented are for newly constructed single and multifamily homes that do *not* participate in the Massachusetts New Homes with ENERGY STAR Program.

The following four measures were selected in consultation with the PAs and ICF, the implementation contractor for the Massachusetts New Homes with ENERGY STAR Program, for modeling maximum compliance savings potential:

- Wall insulation
- Basement insulation
- Proper sealing of ducts in unconditioned spaces
- Fifty percent high efficacy lamp requirement

Each of the measures selected fulfilled at least one of the following criteria:

- Code compliance is expected to be low for at least some builders and not sufficiently enforced by building officials.
- Compliance may be reasonably measured through site visits to completed homes, backed up by a review of the building plans. Duct leakage and lighting are straightforward in this regard.
- The PAs may reasonably be able to affect compliance rates through trainings and other activities.
- Increased code compliance would mean substantial savings, making proposed PA activities worthwhile.

Inputs

The estimation of potential savings from maximum code compliance for each measure is dependent on three key inputs: 1) a forecast of non-ENERGY STAR housing completions in the years 2011, 2012, and 2013; 2) baseline rates of compliance for the four measures studied in the years 2011, 2012, and 2013; and 3) how much energy is estimated to be saved by full compliance with the code per measure. This section explores the first two assumptions; the process for estimating energy savings is detailed in the Methodology section.

Housing Forecast

The housing forecast started with a forecast of all residential housing units completed in Massachusetts. ENERGY STAR units were assumed to be code compliant already, so it was necessary to forecast ENERGY STAR units as a function of all units and subtract them from the total to yield non-ENERGY STAR housing unit completions.

Total housing unit completions forecast. The housing completions forecast used the growth rates found in the McGraw-Hill Dodge Construction (MHC) forecast for the state of Massachusetts for the years 2011, 2012, and 2013. Since the MHC forecast of housing starts and compliance potential is calculated on the basis of housing completions, the MHC data were averaged for every two years, assuming a six-month lag from starts to completions. Thus, the forecasted completions for 2011 are an average of the starts in the years 2010 and 2011; the forecasted completions in 2012 are the average of 2011 and 2012 starts; and so on.

ENERGY STAR housing unit completions forecast. ENERGY STAR housing unit completions had been forecast by ICF for 2011. The forecast for 2012 and 2013 is a function of the percentage of total

housing units that are expected to come in under the Program. Single family ENERGY STAR units in 2012 and 2013 are projected to be 20% of total single family units. While this is high by historical standards, it is reasonable to assume that many new homes built in stretch code communities will come in under the Program resulting in higher penetration rates than in the past.[1]

Over one-half of the multi-family housing units built in Massachusetts over the past two years have come in under the Program. Basically, the downturn in the housing market meant that low-income and affordable units, which are more likely to be ENERGY STAR, formed a much higher percentage of the total multifamily units built. The multifamily penetration rate was set at 40% in 2012 and 33% in 2013 when an expected increase in the housing market will mean more market rate units will be built.

Compliance Rate Forecasts

The estimates of potential savings from full code compliance depend on an assumption of baseline compliance for the first, second, and third years of new home completions under the IECC 2009—that is, 2011, 2012, and 2013. Baseline code compliance estimation began with a review of seven code compliance studies[2], with a particular focus on work that looked at least one of the four measures under consideration. After developing initial compliance estimates from these studies, five informal interviews were conducted: two with local building inspectors, and one each with representatives from ICF, the Board of Building Regulations and Standards (BBRS), and the Massachusetts Department of Energy Resources (DOER). These interviews provided insight into the code enforcement process in Massachusetts, the impact of IECC 2009 on this process, and the challenges that builders will face with the new energy code. The secondary research and interviews were used to develop baseline compliance rates as described in the rest of this section.

Basement wall insulation. Compliance with the basement wall insulation requirements was estimated to be 85% in 2011, increasing to 90% in both 2012 and 2013. Compliance with basement wall insulation should be high in all three years of the code cycle as the requirements did not change from IECC 2006 to IECC 2009.

Lighting. Compliance with the new lighting requirements was estimated to be 75% over all three years of the code cycle (2011, 2012, and 2013). This relatively high compliance rate was chosen for two reasons: 1) the average home only needs to increase the amount of high efficacy bulbs in their home by about 20% (approximately six bulbs) and 2) the lighting requirement is easily verified on site by code officials. Compliance is assumed to remain steady over all three years of the code cycle as light bulbs can easily be removed by homeowners who do not like compact fluorescents after inspection.

Proper sealing of ducts in unconditioned spaces. Compliance with the duct sealing requirements was estimated to be 33% in 2011, increasing to 50% in 2012, and 75% in 2013. The new duct sealing requirements require performance testing of all ducts located in unconditioned space. Initial compliance with these requirements is expected to be low for a number of reasons:

- Builders will need time to adjust to performance testing requirements.

[1] Stretch code communities, established by the Green Communities Act, have building codes that are actually more efficient than needed for ENERGY STAR certification in 2010. Thus, most homes built in those communities, are expected to come in under the Program.

[2] The compliance reports reviewed are listed in the References section.

- It is not clear who will conduct the performance tests (HERS raters, HVAC contractors, etc.), and it will likely take time for coverage to encompass all residential new construction projects.
- Initially, code officials may be lenient and "turn a blind eye" to projects that fail to meet the code requirements.

Compliance is expected to increase substantially in the second and third years of the code as testing encompasses more of the residential new construction market, and code officials enforce the requirements more frequently.

Above grade wall insulation. Compliance with the above grade wall insulation requirements was estimated to be 50% in 2011, increasing to 75% in 2012, and 90% in 2013. The new above grade wall insulation requirements (R-20) present challenges to builders using two-by-six framing techniques. Under the IECC 2006 energy code, builders could use a combination of two-by-six framing and a standard R-19 fiberglass batt to meet the above grade wall insulation requirements. IECC 2009 requires the use of continuous sheathing in combination with cavity insulation, the use of a high density batt, or other nonconventional approaches to meet the above grade wall insulation requirements. For this reason, compliance is expected to be relatively low in the first year of the code as builders will need time to adjust, and code officials may allow for some non-compliance. Compliance is expected to increase significantly in the second and third years of the code as builders adapt to new framing and insulating strategies, and code officials begin to enforce the requirements more frequently.[3]

Methodology

To estimate the potential savings associated with the four measures selected for this study, eQUEST was used to create comprehensive baseline models from a list of baseline assumptions taken from the Massachusetts User Defined Reference Home (UDRH), which was developed as part of the latest baseline study of residential new construction in Massachusetts.[4] The Massachusetts UDRH provided all the baseline inputs with the exception of lighting, which was taken from two more recent reports that more accurately represent the current lighting inventory in Massachusetts residential homes. eQUEST is a comprehensive building simulation program derived from DOE-2 that is able to perform an hourly simulation over one year. Cooling and heating loads are calculated for each hour based on the building system and components input by the user.

These models provided the baseline consumption data against which the measure runs were compared. This was accomplished by first adjusting the baseline models to include installation of all four measures, representing full compliance, and then setting individual measures to the baseline levels described in the preceding paragraph to estimate the energy impact of each of these measures.

Given the new housing stock in Massachusetts, it was determined that conditioned basements (13% of homes), unconditioned basements (74% of homes), furnaces (33% of homes), and boilers (66% of homes) all needed to be modeled. Because the assumptions varied slightly depending upon the type of home (conditioned basement/unconditioned basement) and heating system type (furnace/boiler), multiple baselines were required to establish appropriate starting points from which to estimate measure savings. The

[3] Both of the code officials interviewed indicated that they expected relatively high compliance with the above grade wall insulation requirements. Both cited the fact that simple prescriptive code requirements are relatively easy to verify onsite, in turn increasing compliance.

[4] The latest baseline study at the time eQUEST was run was conducted in 2005; a new baseline study of residential new construction is due to be conducted in 2011 and 2012.

following single-family housing models were developed for this study, distinguishable by the basement and heating system type:

- Conditioned basement with gas furnace
- Unconditioned basement with gas furnace
- Conditioned basement with gas boiler
- Unconditioned basement with gas boiler

All single family homes were modeled with 2,672 square feet of conditioned space and assumed to have central air conditioning, based on the Massachusetts UDRH.

Findings

Potential savings estimation from full compliance for the state of Massachusetts for each measure studied began with developing savings for a composite single family home based on the percentage of new homes accounted for by each of the housing types modeled. The total annual savings for single family homes built each year were calculated as:

> Savings (*measure, year)* = Composite home savings (*measure*) x (1-assumed compliance rate (*measure, year*)) x (Total single family homes (*year*) – ENERGY STAR single family homes (*year*))

Multifamily savings per home were estimated by multiplying single family savings per home by the ratio of square footage for multifamily to single family housing units. This assumes central air conditioning for all multifamily homes.

Total Savings

As shown in Table 1, the maximum potential annual savings from enhanced compliance are close to 30,000 MMBtu for homes built in 2011, falling to 23,000 MMBtu for homes built in 2012, and 13,000 MMBtu for homes built in 2013. Savings in Table 1 include both heating and electric savings converted to MMBtu. Potential annual savings decrease in later years since baseline compliance is assumed to increase as builder experience with the new code and enforcement increase naturally.

Table 1: Maximum Potential Total Annual Savings from Enhanced Code Compliance for Selected Measures (MMBtu)

	2011	**2012**	**2013**
Above grade walls	21,811	14,895	7,616
Duct sealing	7,566	7,712	4,929
Lighting	184	251	321
Basement walls	213	194	248
Total MMBtu	**29,774**	**23,051**	**13,114**

Thus, the total maximum annual savings potential for homes built between 2011 and 2013 is 65,939 MMBtu. Of course, these homes will continue to generate savings throughout their lives. Assuming,

conservatively, 25 year lives for heating and cooling savings due to equipment and shell enhancements and seven year lives for lights, yields a maximum savings potential of 1,634,877 MMBtu from enhanced code compliance over the lives of homes built under IECC 2009.

Enhanced compliance with the wall insulation code provides the bulk of maximum potential savings, primarily from gas savings in space heating, from close to three-quarters of the total in 2011 to almost three-fifths in 2013 as baseline compliance is assumed to improve. Almost all of the remaining maximum potential savings are provided by duct sealing.

Above grade walls offer the largest potential savings opportunity of all four measures. Because all homes have above grade walls, the potential savings from full compliance with the new requirements extend across the entire residential new construction market. Also affecting the potential savings of above grade walls is the fact that the 2005 modeled R-value of R-14.4 is significantly lower than the new requirement of R-20 (R-13+R-5).

Duct sealing offers significant potential savings, as the new code requirements are substantially more efficient than the 2005 baseline measurements. The heating savings from duct sealing are large, but are limited by the fact that two-thirds of homes are assumed to have a boiler with no heating ducts, and 13% of homes are assumed to have a conditioned basement and no duct leakage to unconditioned space. All the homes, including those with boilers, were modeled with central air conditioning. The electric savings from duct sealing, primarily from space cooling, affect all homes except those with a conditioned basement.

Lighting offers the largest potential electric savings. Similar to above grade walls, the potential savings from enhancing compliance with lighting requirements extend across all residential new construction projects. While lighting provides the majority of electric savings, it is negligible compared to the overall savings.

Basement wall insulation offers little savings as compliance is assumed to be high, and the increase in efficiency from the baseline to the new code is minimal at about an R-2 increase.

Electricity Savings

Maximum potential electric savings from enhanced compliance are shown in Table 2. Potential electric savings are fairly constant at around 700 MWh over the three forecasted years because lighting compliance is expected to remain constant. Not surprisingly, lighting provides the bulk of electricity savings followed by duct sealing.[5]

Table 2: Maximum Potential Annual Electric Savings from Enhanced Code Compliance for Selected Measures (kWh)

	2011	**2012**	**2013**
Above grade walls	180,297	123,122	62,956
Duct sealing	178,702	182,139	116,417
Lighting	307,917	420,544	537,595
Basement walls	759	691	884
Total kWh	**667,675**	**726,497**	**717,852**

Again, the maximum annual electric savings potential for homes built between 2011 and 2013 is 2,112 MWh. Assuming 25 year lives for heating and cooling savings due to equipment and shell enhancements

[5] While lighting provides significant kwh savings, it has a negative impact on heating savings since fluorescents are assumed to increase the heating load. The MMBtu savings for lighting shown in Table 1 net out this negative impact.

and seven year lives for lights, yields a maximum savings potential of 30,012 MWh from enhanced code compliance over the lives of homes built in the three years under IECC 2009.

Sensitivity Analyses

As noted earlier, the estimation of maximum potential savings from enhanced code compliance is dependent on the forecasted number of non-ENERGY STAR housing units completed and the assumed baseline rate of code compliance. Since there is more uncertainty over the forecasted values of these two inputs than any of the other assumptions used to generate potential savings estimates, sensitivity analyses were run to examine how much smaller the savings potential would be under more conservative assumptions.

Maximum potential savings from enhanced code compliance would be significantly lower if the housing market did not recover quite as fast as the MHC forecast over the next three years. Similarly, savings would be much lower if the baseline compliance rates with the new code were higher than assumed. In order to gauge the magnitude of potential savings under these conditions, three sensitivity analyses were run:

- Assuming the new housing market grew at one-half the MHC rate
- Assuming baseline compliance with the new code was higher than the original estimate
- Assuming the new housing market grew at one-half the MHC rate and baseline compliance with the new code was higher than the baseline estimate

Lower Housing Forecast

The annual MHC growth rates for the years 2011, 2012, and 2013 were fairly robust, around 30% for single family units and over 40% for multifamily units, reflecting a recovery of new housing construction from the low levels in 2008 through 2010. Thus, even at one-half of the original growth rates, the model assumed that there would be annual growth of 15% to 20% in new housing units completed in Massachusetts. Table 3 summarizes the growth rates used in the original and lower growth case.

Table 3: Forecasted Growth Rates in New Home Completions

	2011	**2012**	**2013**
Single Family			
Original	29%	30%	13%
Lower Growth	15%	15%	7%
Multifamily			
Original	43%	47%	42%
Lower Growth	21%	24%	21%

Higher Baseline Compliance Forecast

Although the initial baseline compliance estimate for basement wall insulation was high (85% in 2010; 90% in 2011 and 2012), it is reasonable to expect even higher compliance is possible considering that the requirements for basement wall insulation have not changed with the new energy code. Compliance with the basement wall insulation requirements was estimated to be 90% in 2011, increasing to 95% in both 2012

and 2013.

Alternative compliance estimates for lighting were increased by 10% from 75% to 85% across all three years. Based on the lighting inventory in the average Massachusetts home, consumers have a relatively small bridge to gap to meet the new code requirements.

Alternative estimates for duct sealing compliance increased from 33% to 45% in 2011, 50% to 65% in 2012, and 75% to 90% in 2013. The reasoning behind the higher compliance estimates is that duct testing could encompass the whole state sooner than expected, and code officials could enforce the code more strictly than initially expected because it is a performance test.

After discussions with code officials, it is reasonable to assume that above grade wall compliance could be higher than initially expected. Code officials said that prescriptive measures are easier to enforce, which could result in relatively high compliance if they inspect them. Under the alternative compliance estimates, above grade wall compliance increased from 50 to 60% in 2011, 75% to 85% in 2012, and 90% to 95% in 2013.

The original and higher assumed baseline compliance rates are summarized in Table 4.

Table 4: Original and Higher Baseline Compliance Rates

	2011	**2012**	**2013**
Original Baseline Compliance Rate			
Above grade walls	50%	75%	90%
Duct sealing	33%	50%	75%
Lighting	75%	75%	75%
Basement walls	85%	90%	90%
Higher Baseline Compliance Rate			
Above grade walls	60%	85%	95%
Duct sealing	45%	65%	90%
Lighting	85%	85%	85%
Basement walls	90%	95%	95%

Savings Potential under Sensitivity Analyses

Under a sensitivity analysis assuming that new housing growth is one-half the rate originally used, maximum potential total savings are about 5,000 to 6,000 MMBtu lower in each of the forecasted years than in the original case. Under a sensitivity analysis assuming a higher baseline compliance rate, maximum potential total savings are about 6,000 to 8,000 MMBtu lower in each of the forecasted years than in the original case. Combining the lower housing growth and higher baseline compliance assumptions yields savings of 9,000 to 12,000 MMBtu lower in each of the forecasted years than in the original case. The original forecasted savings potential and sensitivity analyses are shown in Figure 1.

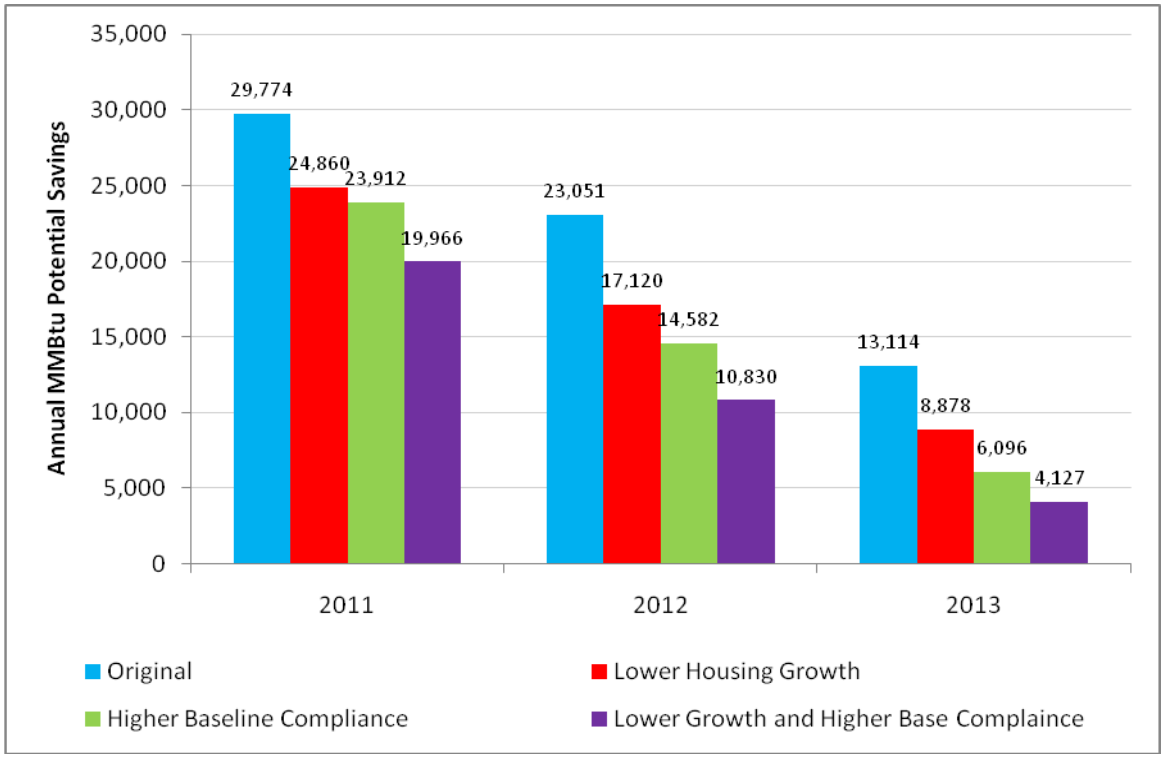

Figure 1: Maximum Potential Total Annual Savings from Enhanced Code Compliance for Selected Measures (MMBtu)—Original Case and Sensitivity Analyses

Thus, the total maximum annual savings potential over the three years for homes built between 2011 and 2013 is 65,939 MMBtu in the original case, 50,858 MMBtu in the lower housing growth case, 44,590 MMBtu in the higher baseline compliance case, and 34,923 MMBtu in the low housing growth combined with higher baseline compliance case. Assuming, again, 25 year lives for heating and cooling savings due to equipment and shell enhancements and seven year lives for lights, yields a maximum savings potential of 1,634,877 MMBtu from enhanced code compliance in the original case, 1,261,423 MMBtu in the lower housing growth case, 1,106,610 MMBtu in the higher baseline compliance case, and 867,058 MMBtu in the lower housing growth combined with higher baseline compliance case over the lives of homes built in the three years under IECC 2009.

Conclusions

The analyses done to date point to sizeable benefits from enhanced code compliance—indeed, the maximum 2011 enhanced compliance potential savings for the four measures studied equals 56% (original case) to 24% (lower growth and higher baseline compliance case) of the MMBtu savings goal for residential new construction programs in Massachusetts in 2011.[6] Several conclusions may be drawn from these findings:

- Measurement of code compliance rates in the field is highly desirable; it will provide accurate baseline compliance rates, which, as shown, affect the maximum savings potential from enhanced compliance. To this end, the Massachusetts PAs are planning to measure

[6] It should be noted that the residential new construction sector forms a small part of the total statewide MMBtu goal; the maximum 2011 enhanced compliance potential savings are less than 1% of the total statewide MMBtu goal.

code compliance in homes built at the end of the IEC 2006 code cycle and at the beginning of the IECC 2009 cycle.

- Compliance enhancement activities must be carefully planned and documented. Homes take time to be constructed and it may be that credit for compliance enhancement is determined a couple of years after the fact.
- The time lag between compliance enhancement activities, which can be expensive, and the resulting savings, which accrue only after homes are built and occupied, needs to be recognized for compliance enhancement activities to fit in with other PA energy efficiency efforts.
- By the same token, unless there is a mechanism for measuring the impact of these activities on energy saved and for attributing these savings to their efforts, energy efficiency programs are unlikely to invest in compliance enhancement.

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