Massachusetts New Homes with ENERGY STAR® Estimated Maximum Potential Savings from Enhanced Compliance with the IECC 2009 Residential Building Code in Massachusetts

FINAL REPORT

October 14, 2010

Submitted to:

Joint Management Committee

Submitted by:

NMR Group, Inc.

Cadmus Group

50-2 Howard Street, Somerville, MA 02144
Phone: (617) 284-6230   Fax: (617) 284-6239
www.nmrgroupinc.com

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Executive Summary

Enhanced compliance with the newly-adopted IECC 2009 building code for non-ENERGY STAR® homes yields significant potential energy savings. Based on discussions with the Program Administrators (PAs) and Program implementation contractor (ICF), four measures—wall insulation, basement insulation, proper sealing of ducts in unconditioned spaces, and meeting the fifty percent high efficacy lamp requirement—were selected for modeling enhanced compliance savings potential.

Potential savings associated with the four measures selected for this study were estimated using eQUEST, a comprehensive building simulation program derived from DOE-2. Noncompliant measures were assumed to be built at levels taken from the Massachusetts User Defined Reference Home (UDRH), which was developed as part of the 2005 baseline study in Massachusetts, 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.

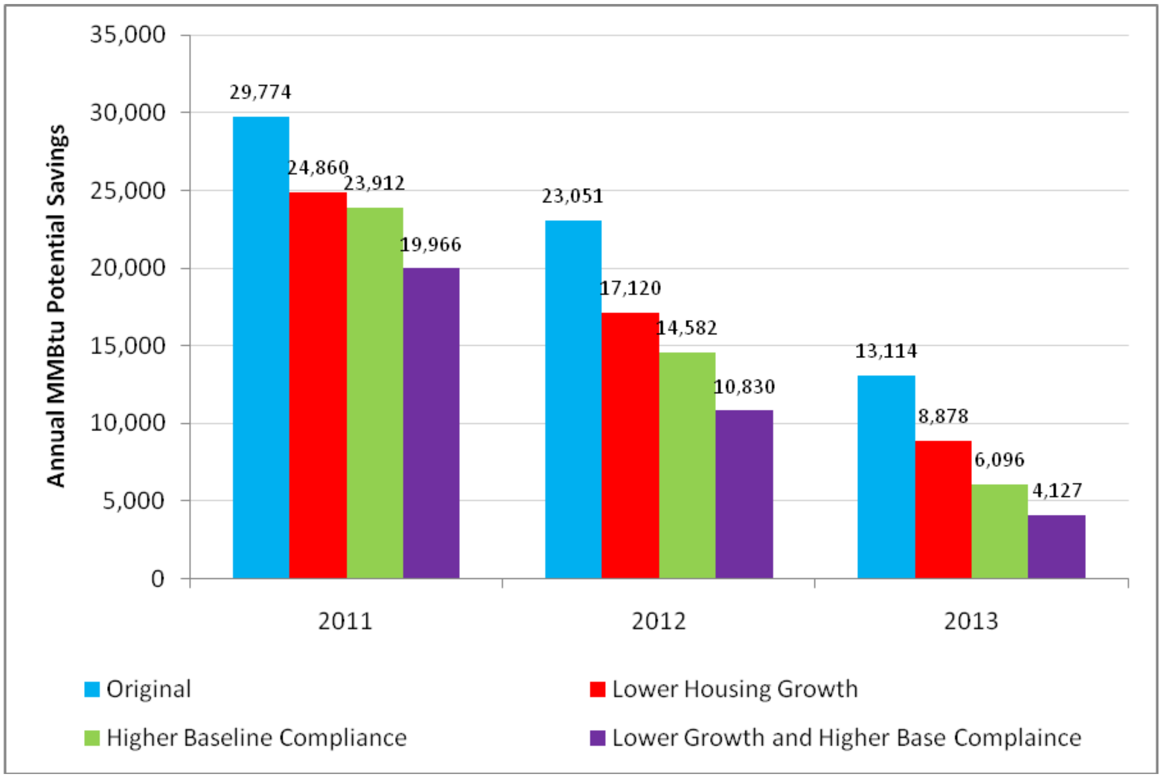
Potential annual savings from enhanced compliance, including electricity savings, for the four measures studied are close to 29,774 million metric Btu's (MMBtu) for homes built in 2011, falling to 23,051 MMBtu for homes built in 2012, and 13,114 MMBtu for homes built in 2013. While the models were run assuming gas heating, heating savings may be allocated to oil or propane according to the new construction baseline. Potential savings decrease in later years since baseline compliance is assumed to increase as builders and other market actors become better able to meet code and code officials increase enforcement. Enhanced compliance with the wall insulation code provides the bulk of energy savings, primarily from 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 potential savings are provided by duct sealing. The lighting code provides the majority of the estimated electricity savings.

Thus, the total annual savings potential for homes built between 2011 and 2013 is 65,939 MMBtu. Assuming, conservatively, 25 year lives for heating and cooling savings due to equipment and shell enhancements and seven year lives for lights, yields a savings potential of 1,634,877 MMBtu from enhanced code compliance over the lives of homes built under IECC 2009.

The estimation of 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. This study has examined how much smaller the savings potential would be under more conservative assumptions. Under a sensitivity analysis assuming that new housing growth is one-half the rate originally used, 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, 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: Potential Total Annual Savings from Enhanced Code Compliance for Selected Measures (MMBtu)—Original Case and Sensitivity Analyses



Thus, the total annual savings potential 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 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 under IECC 2009.

Introduction

The Massachusetts PAs are poised to play an increasingly important role in promoting energy code compliance with the newly-adopted IECC 2009 primarily through trainings of builders, subcontractors, and code officials. This memo presents estimates of the *potential* savings for the years 2011, 2012, and 2013 that may be achieved through compliance enhancement efforts 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 for modeling enhanced 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 fulfills 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.

The estimation of potential savings from enhanced code compliance for each measure is dependent on two key inputs: 1) a forecast of non-ENERGY STAR housing completions in the years 2011, 2012, and 2013; and 2) baseline rates of compliance for the four measures studied in the years 2011, 2012, and 2013.

Housing Forecasts

The housing forecast started with a forecast of all residential housing units completed in Massachusetts. ENERGY STAR units are 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 uses 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.

ICF has already developed a projection of single (one to four unit) and multifamily (five or more unit) housing unit completions in the year 2010 based on the building permits drawn in most of the cities and towns in the state. Two adjustments were performed on the ICF 2010 projections for this study. First, the forecast was adjusted upwards to account for areas with municipal utilities in western Massachusetts and the Unitil territory that were not included in the ICF projections. Based on 2009 Census data,[1] this adjustment increased 2010 projections by 2.6% for single family units and 2.8% for multifamily units.

The ICF forecast was then adjusted to allocate completions in two, three, and four unit buildings to the multifamily category. This was necessary because the model used to develop compliance estimates, described in detail in the Methodology section, was based on single family detached homes. Again based on 2009 Census data,[2] the 2010 projects were allocated assuming 88% of the ICF single family projections are in buildings with one unit, and the remaining 12% are added onto multifamily projections.

MHC growth rates for the years 2011, 2012, and 2013 are fairly robust, reflecting a recovery of new housing construction from the low levels in 2008 through 2010. Applying the MHC growth rates to the 2010 projections yielded the total housing forecast shown in Table 1.

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[1] http://censtats.census.gov/bldg/bldgprmt.shtml

[2] http://www.census.gov/const/C40/Table2/tb2u2009.txt

Table 1: Forecast of All Housing Units Completed in Massachusetts

	Single Family Units	Growth Rate	Multifamily Units	Growth Rate
2010	5,372		3,205	
2011	6,935	29%	4,577	43%
2012	9,038	30%	6,742	47%
2013	10,214	13%	9,542	42%

ENERGY STAR housing unit completions forecast. ENERGY STAR housing unit completions have been forecast by ICF for the years 2010 and 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. In 2010, single family ENERGY STAR units are projected to be 20% of total single family units; this percentage drops to 18% in 2011.[3] For the 2012 and 2013 forecast years, the ratio is assumed to be 20%. 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.[4]

Multifamily ENERGY STAR housing units are projected to be 71% of total multifamily units in 2010, falling to 51% in 2011. The multifamily penetration rate was also high at 63% in 2009. Basically, the downturn in the housing market has meant that low-income and affordable units, which are more likely to be ENERGY STAR, form a much higher percentage of the total multifamily units built. Thus, the multifamily penetration rate is lowered to 40% in 2012 and 33% in 2013 when an expected increase in the housing market will mean more market rate units will be built. Table 2 presents the forecasted numbers of ENERGY STAR units.

Table 2: Forecast of ENERGY STAR Housing Units Completed in Massachusetts

	Single Family Units	Multifamily Units
2010	1,235	1,765
2011	1,385	1,847
2012	2,054	2,204
2013	2,321	2,689

[3] Since the ICF projections define single family as buildings with one to four housing units, the total housing forecast was converted to fit this definition assuming 88% of single family units are in one building and 12% are in buildings with two, three, or four units. ENERGY STAR ratios are based on these numbers.

[4] Based on 2009 Census data, 47 communities have been certified as green communities as of September of 2010. In 2009, these communities accounted for 18% of single family and 11% of multifamily building permits issued.

Compliance Rate Forecasts

The estimates of potential savings from enhanced 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. In order to estimate baseline code compliance, NMR first conducted a review of code compliance studies, with a particular focus on studies that reviewed at least one of the four measures being evaluated for compliance enhancement potential. In total, NMR reviewed seven code compliance studies[5], from which initial baseline compliance estimates were developed for the whole house and the four focus measures.

After developing initial compliance estimates, informal interviews were conducted with a number of local building code experts. 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. Five 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 Department of Energy Resources (DOER). After reviewing code compliance studies and interviewing local experts, the following baseline compliance rates were chosen for the potential savings analysis (Table 3).[6]

Table 3: Baseline Compliance Estimates for Selected Measures

	Basement walls	Lighting	Duct sealing	Above grade walls
2011	85%	75%	33%	50%
2012	90%	75%	50%	75%
2013	90%	75%	75%	90%

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 after inspection, and there is an expected saturation rate for high efficacy bulbs among homeowners.

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

[6] Whole house compliance rates are discussed in Appendix C.

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.
- 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.[7]

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 2005 baseline study in Massachusetts.[8] The Massachusetts UDRH provided all the

[7] 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.

[8] NMR and Dorothy Conant (2006) *Massachusetts ENERGY STAR Homes: 2005 Baseline Study, Part I: Inspection Data Analysis.* May 8, 2006.

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.[9,10] eQUEST is a comprehensive building simulation program derived from DOE-2 that is able to "perform an hourly simulation of the described building for a user-selected one-year time period."[11] 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 removing individual measures to estimate the energy impact of each of these measures.

Based on the 2005 baseline study, 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 to accurately represent the Massachusetts housing stock. 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 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

Based on the 2005 baseline study, all homes were modeled with 2,672 square feet of conditioned space. All homes were assumed to have central air conditioning. More detailed specifications of the modeling inputs are found in Appendix A.

Each of the housing models was used to estimate the baseline energy use for the appropriate home/heating type. The resulting model consumptions are presented in Table 4.

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[9] NMR (2010) *The Market for CFLs in Massachusetts.* January 28, 2010.

[10] NMR, RLW, and GDS (2009) *Residential Lighting Markdown Impact Evaluation.* January 20, 2009.

[11] eQUESTv3 Overview, http://www.doe2.com/download/equest/eQUESTv3-Overview.pdf.

Table 4. Baseline Model Energy Consumption

Housing Type	Model Electricity Consumption (kWh/year)	Model Gas Consumption (MMBtu[12]/year)	Total Consumption (MMBtu/year)
Conditioned basement with gas furnace	3,168	120	131
Unconditioned basement with gas furnace	3,736	146	159
Conditioned basement with gas boiler	3,532	129	141
Unconditioned basement with gas boiler	3,672	128	140

Gas consumption in the baseline models represent energy used for space and water heating, while electricity consumption captures space cooling, pumps and auxiliary equipment, and lighting. With the baseline models and energy consumption established, measure runs were designed to represent full compliance (all four measures) as well as individual measures. Table 5 presents the original baseline values along with the representative measure values based on the 2009 IECC code.

Table 5. Input Values for Baseline and Measure Runs

Measure	Baseline Value	Measure Value
Wall Insulation[13]	R-14.4	R-13+R-5
Below-Grade Wall Insulation[14]	R-11	R-13
Duct Sealing[15]	10% duct loss	5% duct loss
Lighting (lighting power density in watts/sq. ft.)	0.54	0.46

Each of the measure runs was used to estimate the measure's impact on energy use for the four home types. As noted earlier, each housing model was run initially with all measures complying with the new code and savings were calculated relative to a home with all measures at the

[12] MMBtu is millions of Btu

[13] IECC 2009 requires either R-20 cavity insulation, or a combination of R-13 cavity insulation and R-5 continuous sheathing.

[14] Included in conditioned basement models only.

[15] Included in unconditioned basement models only. While the UDRH baseline value for duct leakage was 22 CFM@25Pa/100 ft^2, eQUEST does not allow direct input of leakage based on these measured values. UA values of 24.33 and 20.57 were assigned respectively to the supply and return ducts based on the R-value data used by the models as well as assumptions about duct size. Engineering estimates were used to approximate the percent duct loss appropriate for the baseline and measure values.

baseline level. The effect of full compliance of each measure by itself was calculated by comparing the energy consumption of the home with all measures fully complying and the home with the just the specific measure at the baseline level. The increase in energy consumption was used as the marginal energy savings due to full compliance of that measure. The savings for each single family housing model at full compliance with the IECC 2009 code are presented in Appendix B.

It should be noted that the modeling did not capture potential savings from proper air sealing. As noted in Appendix A, all above grade walls were modeled with infiltration levels representing ACH@50 Pascals of 6.72.[16] This value, an average taken from the Massachusetts UDRH, is actually lower than the IECC 2009 code specifications of 7 ACH@50. However, the 2005 baseline study found infiltration levels varied widely from 2.23 ACH@50 to 14.72 ACH@50. Thus, potential savings from ensuring that all homes reach a minimum infiltration level may be quite sizeable.

Potential Savings

Potential savings estimation from enhanced 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 in Table 4. 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. The MHC forecast includes square footage as well as units of new construction; the average multifamily unit square footage is estimated to be 57% of single family home square footage in 2011, rising to 60% in 2012, and 66% in 2013. Total multifamily savings for each year were then calculated using the equation shown above with the multifamily total and ENERGY STAR homes forecasts.

As shown in Table 6, 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 6 include both heating and electric savings converted to MMBtu. While the models were run assuming gas heating, heating savings may be allocated to oil or propane according to the new construction baseline. Potential annual savings decrease in later years since baseline compliance is assumed to increase as compliance and enforcement increase naturally.

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[16] ACH is air changes per hour and the usual testing procedure is done at 50 Pascals of pressure.

Table 6: 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 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 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 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 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 increased 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 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. 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.

Potential electric savings from enhanced compliance are shown in Table 7. 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.[17]

Table 7: 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	**667,675**	**726,497**	**717,852**

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

Sensitivity Analyses

As noted in the introduction to this memo, the estimation of 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, the sensitivity analyses run involve alternative forecasts for them. Specifically, the sensitivity analyses were designed to examine how much smaller the savings potential would be under more conservative assumptions.

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

[17] 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 6 net out this negative impact.

Alternate housing forecast. Table 8 presents the forecasted total housing unit completions derived by applying one-half the MHC growth rates to the 2010 projections.

Table 8: Alternative Lower Growth Forecast of All Housing Units Completed in Massachusetts

	Single Family Units	Growth Rate	Multifamily Units	Growth Rate
2010	5,372		3,205	
2011	6,154	15%	3,891	21%
2012	7,086	15%	4,811	24%
2013	7,548	7%	5,810	21%

The lower growth forecast of single family ENERGY STAR units was, as in the original case, derived by using the ICF forecast for 2011 and applying a 20% ratio to the total forecast in 2012 and 2013, adjusted to include units in two, three, and four unit buildings as single family homes. In the case of multifamily ENERGY STAR units, however, the ratios applied in 2012 and 2013 were raised from 40% to 50% and 33% to 40%, respectively. The rationale for the higher ratios is that in a slower growing housing market a larger proportion of multifamily units are likely to be low-income or affordable and more likely to participate in the Program. Table 9 presents the forecasted numbers of ENERGY STAR units under the alternative lower growth scenario.

Table 9: Alternative Lower Growth Forecast of ENERGY STAR Housing Units Completed in Massachusetts

	Single Family Units	Multifamily Units
2010	1,235	1,765
2011	1,385	1,847
2012	1,611	1,922
2013	1,715	1,912

Alternative compliance rate forecasts. Table 10 presents the alternative compliance estimates, assuming that compliance is higher than initially anticipated.

Table 10: Alternative Higher Compliance Estimates for Selected Measures

	Basement walls	Lighting	Duct sealing	Above grade walls
2011	90%	85%	45%	60%
2012	95%	85%	65%	85%
2013	95%	85%	90%	95%

Although the initial baseline compliance estimate for basement wall insulation was high (85%), 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.

Alternative compliance estimates for lighting were increased by 10% 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 the first year of the code, 50% to 65% in the second year, and 75% to 90% in the third year of the code. 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 expressed that prescriptive measures are easier to enforce, which could result in relatively high compliance. Under the alternative compliance estimates, above grade wall compliance increased from 50 to 60% in the first year, 75% to 85% in the second year, and 90% to 95% in the third year.

Potential savings under sensitivity analyses. As shown in Table 11, potential total savings under the low housing growth case are about 5,000 to 6,000 MMBtu lower in each of the forecasted years than in the original case.

Table 11: Potential Total Annual Savings from Enhanced Code Compliance for Selected Measures (MMBtu)—Low Housing Growth Case

	2011	**2012**	**2013**
Above grade walls	18,211	11,062	5,156
Duct sealing	6,317	5,727	3,337
Lighting	153	186	217
Basement walls	178	144	168
Total	**24,860**	**17,120**	**8,878**

Again, the total annual savings potential under the low housing growth case for homes built between 2011 and 2013 is 50,858 MMBtu. Assuming 25 year lives for heating and cooling savings due to equipment and shell enhancements and seven year lives for lights, yields a savings potential of 1,261,423 MMBtu from enhanced code compliance over the lives of homes built under IECC 2009.

Under the high baseline compliance assumption case, potential total savings are about 6,000 to 8,000 MMBtu lower in each of the forecasted years than in the original case. (Table 12)

Table 12: Potential Total Annual Savings from Enhanced Code Compliance for Selected Measures (MMBtu)—High Baseline Compliance Case

	2011	2012	2013
Above grade walls	17,449	8,937	3,808
Duct sealing	6,211	5,398	1,972
Lighting	110	153	192
Basement walls	142	97	124
Total	**23,912**	**14,582**	**6,096**

Again, the total annual savings potential under the high baseline compliance case for homes built between 2011 and 2013 is 44,590 MMBtu. Assuming 25 year lives for heating and cooling savings due to equipment and shell enhancements and seven year lives for lights, yields a savings potential of 1,106,610 MMBtu from enhanced code compliance over the lives of homes built under IECC 2009.

The lowest potential total savings occur when the low housing growth and high baseline compliance assumption cases are combined. This sensitivity analysis yields savings 9,000 to 12,000 MMBtu lower in each of the forecasted years than in the original case. (Table 13)

Table 13: Potential Total Annual Savings from Enhanced Code Compliance for Selected Measures (MMBtu)—Low Housing Growth and High Baseline Compliance Case

	2011	2012	2013
Above grade walls	14,569	6,637	2,578
Duct sealing	5,186	4,009	1,335
Lighting	92	112	130
Basement walls	119	72	84
Total	**19,966**	**10,830**	**4,127**

Again, the total annual savings potential under the low housing growth and high baseline compliance case for homes built between 2011 and 2013 is 34,923 MMBtu. Assuming 25 year lives for heating and cooling savings due to equipment and shell enhancements and seven year lives for lights, yields a savings potential of 867,058 MMBtu from enhanced code compliance over the lives of homes built under IECC 2009.

References[18]

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[18] References with a "*" indicate reports that were reviewed to aid in initial compliance estimates.

Appendix A: Detailed Model Inputs

In addition to the inputs described in the main body of the memo, the following assumptions were used to model potential savings from enhanced code compliance for single family homes:

General characteristics. Each of the housing types was modeled with Typical Meteorological Year (TMY) weather data from Boston, Massachusetts, and was designed with 2,672 square feet of conditioned space. This was the average conditioned floor area provided from the baseline, which was assumed to be the same for both conditioned and unconditioned basement models. For homes with unconditioned basements, the conditioned space was modeled entirely above ground, with 891 square feet of unconditioned space located in the basement. Each of the homes was modeled to reflect two above ground floors, with ceiling-to-floor heights of nine feet. This resulted in a one-third increase in wall area for unconditioned basement models relative to conditioned basement models, in turn increasing the potential savings from the above grade wall measure in homes with unconditioned basements.

Roof and ceiling. Each of the housing types was modeled with a pitched roof and attic. While the 2005 baseline study indicated a portion (21%) of the existing single-family construction featured cathedral ceilings (with an average of R-29.58 insulation), the baseline models were designed with all flat ceilings insulated to R-30.99 (the baseline average used as a conservative estimate). It was determined that the energy impact of this difference would be minimal compared to the complexity of modeling homes with a 21% cathedral and 79% flat ceiling.

Floor and slab. The conditioned basement baseline models featured R-11.08 below-grade wall insulation. The unconditioned basement baseline models were modeled without slab insulation, with R-3.12 below-grade wall insulation, and with R-19.4 cavity insulation in the floor above the unconditioned basement.

Walls and windows. All above grade walls were modeled with R-14.4 cavity insulation and infiltration levels representing ACH@50 Pascals of 6.72.[19] Windows were modeled as 18% of the wall area at each orientation and baseline characteristics of U-.37 and a solar heat gain coefficient of 0.35. There were no skylights in the models.

HVAC and ducts. The gas furnace was modeled with an AFUE of 89.2%, whereas the boiler was modeled with an AFUE of 81.7%. The cooling system assumption was a SEER of 13. The 2005 baseline study found that 63% of new homes in Massachusetts had central air conditioning. Due to this, and the fact that the percentage of residential new construction with central air conditioning has likely increased since 2005, all homes were assumed to have a central air conditioning system. Because duct insulation in eQUEST is modeled by assigning heat transfer, and/or duct loss, these values were calculated based on the R-value data collected during the 2005 baseline study. In the case of unconditioned basement models, supply ducts were assigned

[19] ACH is air changes per hour and the usual testing procedure is done at 50 Pascals of pressure.

a UA[20] value of 24.33 and return ducts were given a UA of 20.57 based on the R-value data and assumptions about the duct size. The percent of conditioned air lost through the ducts was assumed to be 10% based on engineering estimates and the 2005 baseline data. The conditioned basement models were designed to reflect 0% duct loss, and were assigned a UA of 0. This was determined to be appropriate due to the fact that duct losses in a fully conditioned home take place within the conditioned space, and are not true losses. While we acknowledge that placing furnaces in unconditioned attics is practiced by some builders in Massachusetts, this scenario was not modeled. The two cases modeled—furnaces in conditioned and unconditioned basements—represent the most common situations and trying to model various scenarios with furnaces in the attic would have greatly increased the complexity of the analysis for little additional accuracy in the results.

Lighting. A lighting power density (lpd) of 0.54W/sqft was calculated for the baseline models from Massachusetts on site lighting data, which indicated the percent of hardwired lighting sockets assigned to incandescent or halogen bulbs (69%), fluorescent tubes (8%), and CFLs (23%).[21]

Schedules. Lighting schedules were adjusted to reflect usage data collected through recent Massachusetts site visits, which indicated daily average annual use of approximately 2.8 hours.[22] Cooking and "Miscellaneous" schedules were also modified for consistency. Heating and cooling schedules were modified to reflect common residential set-points as determined by engineering estimates as follows:

- Heating – Occupied/Unoccupied: 70degF/65degF
- Cooling – Occupied/Unoccupied: 75degF/79degF

Occupancy schedules were set to represent full occupancy (100% occupied) between the hours of 6pm and 7am on weekdays. On weekends, occupancy was set at 100% between the hours of 5pm and 8am, and 50% between 9am and 4pm.

[20] The UA is a measure of the amount of heat that would be transferred through a given surface or enclosure (such as a building envelope) with a one degree Fahrenheit temperature difference between the two sides. The UA is calculated by multiplying the U-Value by the area of the surface (or surfaces).

[21] NMR (2010) *The Market for CFLs in Massachusetts.* January 28, 2010.

[22] NMR, RLW, and GDS (2009) *Residential Lighting Markdown Impact Evaluation.* January 20, 2009.

Appendix B: Savings for Single Family Housing Types at Full Compliance with IECC 2009

Housing Type	Run #	Measures	Model Consumption (kWh)	Model Consumption (MMBtu)	% kWh Savings	%MMBtu Savings	Total % Savings
Cond. Basement, Gas Furnace	1	All Measures	2,869	112	9.5%	6.7%	6.9%
	2	Lighting	3,128	111	8.2%	-0.5%	0.2%
	3	Below-Grade Wall Insulation	2,868	113	0.0%	0.7%	0.6%
	4	Wall Insulation	2,942	120	2.3%	6.5%	6.1%
Uncond. Basement, Gas Furnace	1	All Measures	3,287	131	12.0%	10.1%	10.3%
	2	Lighting	3,517	131	6.2%	-0.4%	0.1%
	3	Duct Sealing	3,402	136	3.1%	3.5%	3.5%
	4	Wall Insulation	3,359	140	1.9%	5.9%	5.6%
Cond. Basement, Gas Boiler	1	All Measures	3,228	121	8.6%	6.0%	6.2%
	2	Lighting	3,455	121	6.4%	-0.5%	0.1%
	3	Below-Grade Wall Insulation	3,237	123	0.2%	1.5%	1.4%
	4	Wall Insulation	3,297	128	1.9%	5.0%	4.8%
Uncond. Basement, Gas Boiler	1	All Measures	3,355	120	8.6%	5.9%	6.1%
	2	Lighting	3,586	119	6.3%	-0.5%	0.1%
	3	Duct Sealing	3,379	120	0.6%	0.0%	0.0%
	4	Wall Insulation	3,418	128	1.7%	6.4%	6.0%

Appendix C: Whole House Compliance Estimates

As part of the codes and standards evaluation, the NMR team estimated what whole house compliance will be with the new energy code. Whole house compliance does not affect the potential savings listed in this memo, but it is a valuable tool for codes and standards evaluation. As with the four measures presented in this memo, whole house compliance was estimated through a review of secondary sources and through informal interviews with local building energy code experts.

A home is considered compliant in one of three ways: the prescriptive path, the UA alternative path (REScheck), and the performance path (HERS rating). The prescriptive path requires that the home meets all of the requirements listed in the prescriptive tables of IECC 2009. The UA alternative path is similar to the prescriptive path, but allows for UA tradeoffs between areas of the thermal envelope. Finally, the performance path requires that the home be modeled to have a lower annual energy cost than the IECC 2009 reference home. The performance path takes into account different variables such as air and duct leakage results.

Whole house compliance was estimated to be 33% in 2011, increasing to 50% in 2012, and 66% in 2013. Initially, we expect whole house compliance to be low among non-ENERGY STAR homes due to the difficulty of meeting new duct leakage, above grade wall, and air sealing requirements. As builders move into the second and third years of the code, we expect compliance to increase due to familiarity with the code and an increase in performance testing. As builders familiarize themselves with duct testing requirements and possibly third party HERS raters, it is likely that we will see an increase in performance testing. The rationale for this is that if builders are contracting HERS raters to conduct duct leakage tests they may go the extra mile and utilize the performance path for compliance.