IMPACT ANALYSIS OF THE MASSACHUSETTS 1998 RESIDENTIAL ENERGY CODE REVISIONS

Prepared for

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Boston, Massachusetts

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S EXECUTIVE SUMMARY

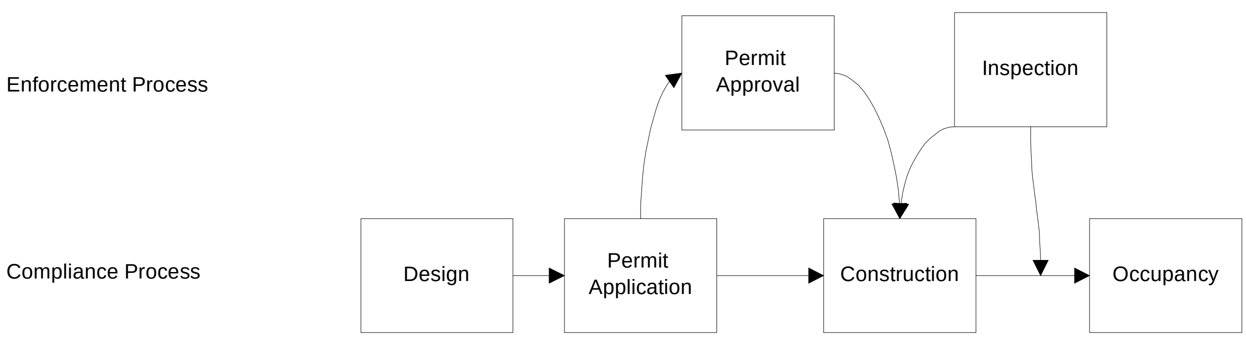
On March 1, 1998, a new residential energy conservation code went into effect in Massachusetts.[1] This report presents the results of a study of compliance with this code and its impacts. The study has been conducted for the Massachusetts Board of Building Regulations and Standards (BBRS) by a team of consultants led by XENERGY, Inc.[2]

Although the new code provisions afford builders and architects greater design flexibility, they entail potentially greater complexity. Thus, the code revisions have the potential for yielding greater energy savings, but if there is inadequate compliance or enforcement, the benefits of the new code will be diminished. This study addresses the overall effects of the new code, taking into account the degree of code compliance, energy and air emission savings attributable to the new code, and the attitude of builders, code officials, and others toward the new code.

S.1 APPROACH

To provide context for this study, it is useful to identify the steps in the process through which an energy code affects the performance of a new building. Figure S-1 shows the key steps from

Figure S-1
The Building and Compliance Process



building design through occupancy. The figure shows two paths—one is the **compliance process** through which the building industry achieves compliance with the code and the other is the **enforcement process** through which building officials enforce the code to ensure compliance.

[1] *780 CMR Appendix J. Energy Conservation Code for New Construction Low-Rise Residential Buildings.*

[2] Other team members included Peregrine Energy Group and RISE Engineering.

During the design process, the designer needs to prepare a design that complies with the code. The design information is incorporated in the permit application. The code official is responsible for ensuring that the proposed design meets the code requirements and construction can then proceed. During construction, the builder and subcontractors need to incorporate the features identified in the permit application that are required for compliance. To ensure this happens, code officials conduct inspections with a final inspection usually occurring after construction is completed. The buyer then takes possession of the house and occupies it.

The effects of the 1998 code revisions depended on the actions that occurred at each step in the process shown in Figure S-1. Ultimately, performing to the requirements established by the code required builders to build houses that met the code and building officials to conduct the necessary inspections and enforce the code requirements. In this study, we used both onsite building data collection and building market player interviews to assess how successful compliance and enforcement have been.

To evaluate the impacts of these code revisions, we completed the following data collection steps and analyses:

- Conduct builder interviews and review existing studies to compile residential baseline (pre-code revisions) construction characteristics
- Identify a representative sample of new houses
- Compile building data for each house from the local building official's office
- Conduct onsite surveys of each house (186 surveys were completed) and document actual construction characteristics
- Select a sample of residential market actors and conduct in-depth interviews on their code perceptions, awareness, knowledge, and attitudes
- Analyze code compliance of each surveyed house based on thermal performance requirements, specific construction requirements, and equipment sizing
- Identify factors responsible for noncompliance
- Investigate relationships between compliance and market and housing factors
- Estimate energy savings and emissions impacts of the code revisions relative to the baseline construction practices.

S.2 MAJOR FINDINGS AND CONCLUSIONS

Major findings and conclusions are presented in four areas—observations about the code and implementation process, compliance rates and factors related to compliance, causes of noncompliance, and code energy and emissions impacts.

S.2.1 Observations about the Code and Implementation Process

Based on feedback from market actors, the BBRS has done a good job of informing residential construction professionals about the features of the code regarding the design, permit application, and construction requirements for new residences. Code awareness and understanding appeared to be quite good two years after the code changes had gone into effect. All market actor groups indicated, however, that they could use more information on energy efficiency, particularly on new products and techniques. Most indicated that they looked to the BBRS and its trainings, professional organizations, and other professionals for information.

The acceptance level of the revised code was generally quite high. Many market actors noted that the code requirements had increased the overall quality of houses being built, and particularly cited the NFRC certification requirement for windows as a significant upgrade.

The use of MAS*check* was the most common method to demonstrate compliance at the permit stage. All the local building code officials we interviewed used MAS*check* reports to verify compliance and market players accepted the need to use MAS*check*. Most players were supportive of MAS*check* and its flexibility, but relatively few made use of that flexibility. Several designers noted that the MAS*check* Windows™ operating system format was not compatible with their MacIntosh™ and CAD design systems.

Although MAS*check* was widely accepted, only a few communities crosschecked building specifications on the MAS*check* printout against the building plans or performed any site checking between MAS*check* and what was actually constructed; our onsite surveys confirmed that large discrepancies often existed between the data in the filed MAS*check* output and the characteristics of the building as-built. This suggested a potential downside to the use of MAS*check*—some code officials may have begun to rely on the initial MAS*check* filing as an adequate verification of code compliance and not followed through adequately during construction and post-construction inspections to verify compliance of the constructed building.

Other major observations on the code and compliance process were the following:

- Building industry members and code officials suggested there was a need for a more checklist-oriented approach for energy-efficiency requirements, especially as a means to organize the inspection process.
- Market actor interviews and onsite surveys indicated that code official inspections of insulation, penetration sealing, and duct sealing requirements were often insufficient, and varied considerably by geographic area.
- Filings with building departments were insufficient in almost a third of the cases to determine how energy code compliance was determined.
- Although some builders were interested in prescriptive approaches, only 2% of the houses used the prescriptive package compliance approach.
- Energy-code enforcement varied significantly among communities, although the variation was not substantially different from other parts of the code.

S.2.2 Compliance Rates and Factors Related to Compliance

We found that only 46.4% of the houses complied with the overall thermal performance (UA) requirements of the code. Although less than half the houses complied strictly with the code thermal performance requirements, only 20% exceeded the compliance threshold by more than 10%.

Specific compliance findings included the following:

- As-built characteristics often differed markedly from the characteristics in the permit documents—areas and perimeters varied significantly in nearly 80% of the cases and insulation levels differed substantially in about one-third of the cases.
- More than 80% of the houses did not meet penetration or duct system sealing requirements.[3] Our duct system tests showed that the average losses to outside the house envelope were about 22%, or about twice what good sealing practices can achieve.
- Air infiltration data, however, showed that most house envelopes were sealed well enough to achieve relatively low infiltration rates.
- The average heating system was oversized by 35% over what the code allowed. On the other hand, cooling systems typically met the sizing requirements.
- Houses heated with natural gas or propane were much more likely to comply with the code than those heated with oil (only a little over a third of these houses complied with the code). Houses with furnaces were twice as likely as those with boilers to meet the code. Both these results were related to the fairly common use of high efficiency (>90% AFUE) gas furnaces.
- Compliance rates were considerably lower in the coldest areas of the state—only about one-third of the new houses met the code requirements in the coldest areas.
- There was some evidence that the compliance rates were lower in the areas where code officials had to inspect and approve more houses, but the differences were not statistically significant.
- Based on self-reported thermostat setpoints, only a small proportion of occupants regularly set back their thermostats during the night and unoccupied periods.

S.2.3 Causes of Noncompliance

Because this code was performance-based, it was not possible to pinpoint specific areas of noncompliance. However, comparing the characteristics of complying and noncomplying houses revealed which features contributed to noncompliance. Based on this analysis, we drew the following conclusions:

- Noncomplying houses typically had less insulation in wall cavities.
- Noncomplying houses usually had less insulation in floor cavities. The average R-value in noncomplying houses was about R-2 less than in complying houses.
- Noncomplying houses were very unlikely to have continuous insulation in the envelope components.
- Noncomplying houses, on the average, had heating equipment that was about three percentage points less efficient than the equipment in complying houses.

[3] We took a strict "all or nothing" approach in assessing compliance with the sealing requirements.

- Poor duct sealing practices contributed to noncompliance.

S.2.4 Energy and Emissions Impacts of the Code

The energy code provided direct energy savings for occupants and emissions reductions that benefited society at large. Table S-1 summarizes the estimated annual space heating and cooling (central air conditioning only) energy savings resulting from the code. Average air conditioning savings were about 6% and space heating savings were about 23% of the baseline levels.[4]

Table S-1
Annual Energy Savings per House

	Space Cooling Electricity, kWh	Space Heating, All Fossil Fuels, Therms
Complying Houses with Equipment	196	302
Noncomplying Houses with Equipment	136	231
% Population with Equipment	58.1%	100%
Average over All Houses	97.9	264
Average % Savings Relative to Baseline	5.9%	23.4%

The table shows that, on the average, energy savings occurred for both houses that complied and did not comply with the code. However, the space heating and cooling energy savings for complying houses were about 50% larger than they were for noncomplying houses.

Reduced use of fossil fuels for heating and electricity for cooling produced emissions reductions. Table -S-2 summarizes the annual reduction in emissions estimated for all new houses constructed under the revised code in 2000.

Table -S-2
Average Annual Emissions Savings

	SO_x	NO_x	CO_2
Total Savings for New Houses	30.4 ton/yr	24.5 ton/yr	26,600 ton/yr
Note: Estimate of new houses is based on U.S. Census data for housing units authorized (14,442) in 2000.			

[4] We note that these estimates were based on a simulation model and, since data were not available on actual consumption, the results may overstate or understate the actual impacts.

S.3 RECOMMENDATIONS

Based on the study findings and conclusions, we developed recommendations in four areas. These are presented below.

- Specific types of training and information dissemination should be implemented to increase code awareness, understanding, and compliance

  ⇒ The BBRS should institute additional training in the areas and on the topics identified below.
  ⇒ Other types of information dissemination should be implemented and targeted at the topics and market actors that will be most influenced to increase code compliance. The BBRS should work with respected professional organizations to train their members and help disseminate information.
  ⇒ Refresher training should be offered for code officials and others who have already been trained.
  ⇒ Training should be offered for code officials who missed the first round of training. Training should be implemented to improve consistency in how the code is enforced across jurisdictions.

- Specific messages, information, and materials should be developed and disseminated

  ⇒ Market actors should be made aware of what the impacts are of not meeting the code and how often new houses fail to meet it.
  ⇒ Information on good or exemplary practices and improved energy-efficiency technologies should be compiled and made available to builders and their contractors. Code officials also should be informed of these practices and technologies so that they can expedite acceptance of them under the code and communicate to other code officials and builders about their suitability.
  ⇒ Market actors should be informed about areas in which compliance has been poor, such as sealing of ducts, heating equipment oversizing, and sealing of penetrations.
  ⇒ Tools should be developed to simplify compliance and enforcement. Two examples are standardized checklists to verify compliance and heating/cooling system efficiency and sizing checklists or sheets.
  ⇒ The code language regarding sizing of combined space and water heating equipment should be clarified.
  ⇒ Information on the benefits of thermostat setback/setup during appropriate times should be compiled and disseminated through channels that will reach homeowners.
  ⇒ The development of a MacIntosh™-compatible version of MAS*check* should be explored.
  ⇒ The feasibility of providing annual updates of the building code through the State Bookstore on searchable CD-ROMs should be assessed.

- Information dissemination and training should be targeted

  ⇒ Builders should be specially targeted for training and information dissemination. Designers and suppliers could be used as information channels to reach builders.
  ⇒ Information and training on proper sizing of heating and cooling equipment should be targeted to contractors that install these systems. Equipment distributors might serve as an effective channel for educating these contractors.
  ⇒ Code officials also should be targeted to inform them about how often new houses fail to meet the code and the impacts of noncompliance on homebuyers.
  ⇒ Information should be targeted to homebuyers on the benefits of meeting the code, things to look for to ensure a new house complies, and good operating practices.
  ⇒ Special efforts should be directed at increasing compliance of houses with oil heat and at improving compliance in the coldest parts of the state.

- Specific practices and procedures should be improved

  ⇒ Code officials should verify construction practices against the original compliance documentation, or require that compliance of houses as-built be verified.
  ⇒ All building departments should establish practices to ensure that all materials are present for each house. Manufacturers' cut sheets on windows, doors, and heating/cooling equipment should be included in the files to facilitate compliance verification.
  ⇒ Builders and their contractors should increase their use of foam sealants to reduce infiltration, apply mastic to seal ducts, and size heating equipment appropriately.
  ⇒ Special attention should be directed to increasing the use of a more whole-building approach to the design, construction, and compliance process. In general, approaches are needed for improving communications between the builder (prime contractor) and the subcontractors and suppliers so that new houses are treated more as integrated systems.
  ⇒ Builders should increase their use of higher insulation levels in floors and walls and use continuous insulation where appropriate to comply with the code.
  ⇒ The market for prescriptive approaches to compliance should be investigated further.

1 INTRODUCTION AND OVERVIEW

On March 1, 1998, a new residential energy conservation code went into effect in Massachusetts.[1] This report presents the results of a study of compliance with this code and the code's impacts. The study has been conducted for the Massachusetts Board of Building Regulations and Standards (BBRS) by a team of consultants led by XENERGY, Inc.[2]

The new code provisions afford builders and architects greater design flexibility by more clearly allowing trade-offs between different building components and between the building envelope and heating equipment efficiencies. Further, the new code, is intended to reduce energy consumption relative to the code requirements previously in place for most low-rise residential buildings in most locations in the state. These benefits, however, are achieved by potentially greater complexity, either real or perceived, in the code language and code compliance requirements. While the new code may yield greater energy savings and be technically improved, if there were inadequate compliance or enforcement, the benefits of the new code would be diminished. This study addresses the overall effects of the new code, taking into account the degree of code compliance, energy and air emission savings attributable to the new code, and the attitude of builders, code officials, and others toward the new code.

1.1 OVERVIEW OF THE ENERGY CODE

The revised code provisions are contained in the Massachusetts 780 CMR Appendix J *Energy Conservation for New Construction Low-Rise Residential Buildings.* They are based on the Council of American Building Officials Model Energy Code 1995 (MEC 95). The provisions apply to new residential occupancy buildings and additions to existing residential buildings three stories or less in height. The code regulates building design and construction to achieve required levels of thermal resistance (U-value), air leakage, and space heating and cooling and water heating equipment efficiencies. It also requires that window U-values be determined in accordance with the National Fenestration Rating Council (NFRC) 100 and labeled and certified by the manufacturer.

The code also includes a set of generic requirements that address the following specific practices:

- installation of an approved vapor retarder in frame walls, floors, and ceilings
- insulation of exterior walls of basements
- insulation of slab-on-grade floors
- insulation of floors above crawlspaces
- insulation of access openings
- return-air ceiling plenums.

[1] *780 CMR Appendix J. Energy Conservation Code for New Construction Low-Rise Residential Buildings.*

[2] Other team members included Peregrine Energy Group and RISE Engineering.

It also establishes requirements to limit air leakage through window and door assemblies; joints, seams, or penetrations in the building envelope; and recessed lighting fixtures. The code also specifies required space heating and cooling load calculation methods, heating and cooling equipment sizing requirements, equipment efficiency performance requirements, and heating and cooling system controls requirements.

Additional requirements apply to air distribution system insulation and sealing for forced-air systems and piping insulation for boiler systems.

The code provides flexibility to builders through five methods for demonstrating energy code compliance. The prescriptive package method specifies required insulation levels, window U-values, and equipment efficiency levels. The requirements vary based on climate (defined by heating degree-days, HDD) and window area (as a percent of gross wall area). The second method, the component performance approach, allows the builder to demonstrate compliance using a tradeoff approach that takes into account tradeoffs among all building envelope components and heating and cooling system efficiencies. The third method, the MAS*check* software approach, allows the builder to run a software tool designed to check compliance based on the building components proposed by the builder. This approach was anticipated to be, and has been in fact, the most common approach used. The fourth approach is the systems approach. This approach requires an annual energy analysis for the proposed building compared to a standard building designed to just meet the code. The fifth approach, design utilizing renewable energy sources, allows the builder to use the systems approach and to discount a portion of the building's calculated energy use if energy is provided by solar, geothermal, wind, or another renewable energy source.

1.2 STUDY PURPOSE AND OBJECTIVES

The overall purpose of this study was to assess the effects of implementing this code now that it has been in effect for over two years. By documenting actual building practices under the code, this study was intended to document the real-world impacts of the code, taking into account the realities of implementing the code.

The purpose of this study was accomplished through the following five objectives:

1. Determine current construction practices based on a review of building permits and building compliance documents and nearly 200 onsite surveys of newly constructed houses.
2. Assess the level of code compliance based on the onsite survey data and document causes of noncompliance.
3. Compare current construction practices to construction practices prior to the new code.
4. Estimate energy use savings and air emissions reductions due to the new code.
5. Assess the attitudes of key market actors toward the new code and document their perceptions.

1.3 STUDY COMPONENTS

Three types of data and information were collected and then analyzed to fulfill this study's objectives. First, we reviewed data from two 1995 baseline construction practices surveys that could be used to provide data on building practices prior to the code revisions. We also conducted a survey of builders in Massachusetts to obtain information on what their building practices were just prior to implementation of the new code.

Second, we conducted detailed reviews of the construction characteristics of nearly 200 recently constructed homes in Massachusetts. This process included collecting building department information along with compiling detailed building characteristics data from an onsite survey of each house in our sample.

Third, we conducted in-depth interviews with key market actors on the supply-side of the housing market and with building code officials. Most of these interviews were conducted in-person, but some were conducted by telephone, as needed.

1.4 STUDY APPROACH

The details of each step in our approach are discussed in subsequent sections of this report. Here we provide an overview of the approach.

The baseline building construction data (which was primarily from one of the 1995 surveys) provided the starting point for measuring the effects of the new code on energy use and air emissions. The baseline data were for those construction characteristics that were expected to change under the new code. These included building envelope insulation levels, window types and characteristics, space heating and cooling equipment efficiency levels, and air infiltration rates. The baseline data provided average efficiency or performance values for building components and equipment that could be assumed to be what was installed in a typical home prior to the 1998 code changes.

The onsite surveys of 2000 current practice building construction data provided the key inputs to several analyses. First, the data allowed us to document current construction practices for a very large number of characteristics related to energy efficiency including window area, window type, envelope insulation levels, floor area, natural infiltration rates, etc. Second, the data were used to determine whether each home surveyed actually met the efficiency requirements of the new code. Based on these data, we were able to determine if each home complied with the code and the overall compliance level. Third, these data allowed us to explore what factors were responsible for noncompliance in homes that did not comply.

Fourth, the data for each house were input into a building energy simulation model (DOE-2) to calculate the estimated annual energy consumption for each building. Each building was then reanalyzed assuming that the insulation levels, windows, etc. had the typical characteristics based on the baseline construction data instead of the actual characteristics. These analyses provided an estimate of how much energy was saved by building to the new code and how much the code reduced air emissions associated with the energy used in each building. These results were then aggregated and we also estimated the savings by different building segments (climate zone, price, etc.).

Fifth, the onsite survey data also permitted us to analyze specific issues related to code implementation and building practices. Two key issues of interest were the energy losses from home air distribution systems and the sizing of heating and cooling equipment.

The in-depth interviews with key market actors allowed us to examine process and implementation issues related to the code. We documented the responses of different market actor groups to questions about their understanding of the code, how it was implemented, problem areas, and other topics that helped identify implementation issues and recommendations for actions to address those issues.

1.5 REPORT CONTENTS

This report presents study findings at three different levels of detail to match up with the reader's interests. The Executive Summary briefly discusses the approach and highlights the key findings and recommendations for the reader who wants an overview of the study without details of the approach and results. Sections 2 through 7 present more comprehensive information on how the study was conducted and highlights of the findings on topics that were identified as being of primary interest. The appendixes are included for the reader who wants more detailed information about specific findings from the onsite surveys and more details on the market actor interviews.

Section 2 of this report discusses the baseline building construction data we used. It describes the data sources and values compiled.

Section 3 describes the steps taken to design a sample for collecting current practice building construction data and the data collection process. Section 4 describes how we analyzed the current practice construction data to characterize current construction practices, assess code compliance, and estimate code effects on energy consumption and air emissions.

Section 5 presents our key findings based on the construction databases. It first presents information about the level of code compliance. Next, it presents our estimates of energy consumption and emissions reductions resulting from the new code. Third, it summarizes key construction characteristics for houses built under the current code.

Section 6 presents information from the market actor interviews. It discusses what groups we interviewed, how we selected interviewees, how we collected the data, and what we found from the interviews.

Section 7 presents a summary of key conclusions from this study and recommendations about how to improve the code and code compliance.

Appendix A presents the data collection form used to collect the onsite data. Appendix B presents detailed data from the onsite survey. Appendix C summarizes the results from the onsite data segmentation analyses. Appendix D presents a detailed discussion of the market actor interviews and the protocols used for the interviews.

2 BASELINE CONSTRUCTION DATA

This section discusses the sources of construction characteristics data that we used to establish baseline efficiency levels prior to the code revisions.

2.1 OVERVIEW

To estimate the energy and emission effects of the code revisions, it was necessary to determine the characteristics of homes as they would have been built in the absence of the revisions. Because no construction survey was conducted just prior to code implementation, we had to rely on other sources.

One source was a study done in Massachusetts in 1995 that documented construction characteristics of gas-heated homes built at that point in time. Our second source was a phone survey of 50 builders that we conducted in 1999. These builders were asked what insulation levels, window types, etc. they typically installed in 1997.

For the reasons discussed later, we determined that data from the 1995 study were more reliable in general. Consequently, this study was our primary source of baseline data.

2.2 1995 BASELINE STUDY

The data collection procedures used in the 1995 study were very similar to those employed in our onsite building surveys for the current study.[1] Onsite surveys were conducted for 224 homes in 25 towns.

The surveys collected data on a comprehensive set of building components and equipment. They included dimensions and insulation levels of all envelope components, efficiencies of heating and cooling equipment, window areas, and water heater characteristics. In addition, blower door tests were conducted to estimate infiltration rates in each house.

There was one area in which there was uncertainty about using these data. All the houses surveyed were heated with natural gas, but there was the possibility that the houses we surveyed in 2000 would have different heating fuels. In fact, a substantial proportion of the homes in our study were heated with oil. However, the code in effect before 1998 had the same prescriptive efficiency requirements for houses heated with gas or oil. Consequently, there was no reason to expect that the efficiency characteristics of oil-heated houses would differ from those of gas-heated houses. On the other hand, the requirements for electrically heated houses did differ from those for fossil-fueled houses. However, our random sample of houses surveyed in the current

[1] XENERGY. 1995. *Final Report: Characterization of Residential New Construction Building Practices in Gas-Heated Homes in Massachusetts*. Prepared for Bay State Gas, Berkshire Gas, Boston Gas, Colonial Gas, Essex County Gas, and Fall River Gas. Burlington, MA

study did not include any heated with electricity so there was no need to have baseline data for electrically heated houses.

The infiltration rates were estimated in the 1995 study using the same technique employed during the onsite surveys for our current study. As will be discussed later, the average rates measured in the 1995 study were considerably higher than the average rates we measured in the current study. We found no factor other than implementation of the new code that could explain the substantial improvement in infiltration rates.[2] No other data were available for 1997 construction practices in Massachusetts.

2.3 2000 BUILDER SURVEY

We also contacted a sample of 50 builders in Massachusetts to ask them about their energy-efficiency building practices in 1997 as a way to provide additional baseline construction data. We asked specifically what the typical envelope R-values, window types, foundation types, and equipment types and efficiencies were that they were installing in 1997.

The data collected from this process were limited, however, in three major ways. First and most important, it appeared that builder recollections of what they did three years ago were probably not sufficiently accurate. In general, it appeared that builders overstated, on the average, the R-value of insulation that they installed. We concluded this because the average values reported were higher than what our onsite survey data indicated builders were installing under the revised code. The values also were higher in most cases than the values reported in the 1995 onsite surveys. There was no reason why insulation levels would have increased and then decreased from 1995 to 2000.

Second, it appeared that builders did not interpret questions about some of the building components as intended and, as a result, they provided responses that were not accurate. This was particularly true of data provided on basement wall insulation levels.

Third, the sample of builders we interviewed was relatively small and this affected the accuracy and precision of estimates. This was especially true when we disaggregated the results by climate zone. For example, only one builder we interviewed was in climate zone 1.

Fourth, for heating equipment builders are often not very knowledgeable about exactly what is installed in their homes. An HVAC contractor usually makes the final determination so builder responses on equipment efficiency levels are not likely to be very accurate.

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[2] For example, one possibility was reduced infiltration from the use of vinyl windows in place of metal frame windows. However, vinyl windows were by far the most common window type in houses surveyed for the 1995 study as they were in our recent surveys. Another possibility was changes in the infiltration test procedures, but we were unable to identify any notable changes that could have accounted for the differences in the measured values.

As a result of these limitations, we chose to rely on the 1995 study data rather than the builder survey for most of the baseline information. In one important area, however, the builder survey data were very useful. We asked builders about the characteristics of the windows they installed in 1997. Most could not tell us the U-value of the windows, but almost half provided descriptions of their windows. They provided the number of panes, frame type, whether or not the glass had a low-emissivity (low-E) coating, and whether or not the space between panes was gas-filled. Both because builders were likely to have a better recollection of the window characteristics than specific quantitative characteristics such as R-values or U-values and because window efficiencies have improved during the past 5 years, we used the builder survey information to characterize windows installed in 1997 rather than the 1995 data.

2.4 BASELINE CHARACTERISTICS DATA

The baseline building component and equipment measures used in this study are shown in Table 2-1. The table also describes the source and rationale for selecting each of the characteristics to represent a baseline building.

Table 2-1
Baseline Component and Equipment Efficiency Level

Component/Equipment	Value Selected	Source and Rationale
Heating System	**AFUE, %**	
Gas Furnace	85.7	See (1) below
Gas Boiler	81.2	(2): 1995 survey provided credible results from large sample and there is little evidence of significant changes in gas boiler efficiencies.
Oil Furnace	82.2	(3): There is no evidence supporting a decline in oil furnace efficiency suggested by builder data; current survey is based on onsite data.
Oil Boiler	83.0	(3): Current survey is based on onsite data; there are only 10 observations in builder survey.
Air Conditioner	**SEER**	
Cooling Efficiency	10.3	(2): 1995 survey was based on a large sample; only one builder provided data in builder survey.
Window Efficiency	**U-value**	
Windows	0.495	(4): The 1995 data probably don't reflect recent trends in window upgrades. The builder data come from window descriptions, which are probably more reliable than U-values reported by builders.
Exterior walls	**R-value**	
Cavity	13.6	(2): 1995 survey was based on a large sample. Recall and sample size restrict the validity of the builder data.
Sheathing	0.13 (averaged over all homes)	(2): 1995 survey was based on a large sample. Recall and sample size restrict the validity of the builder data.
Heated Basement Walls	7.3	(2): 1995 survey was based on a large sample. Recall and sample size restrict the validity of the builder data.
Unheated Basement Walls	3.2	(2): 1995 survey was based on a large sample. Recall and sample size restrict the validity of the builder data.
Floors	**R-value**	
Over Unheated Basement	17.6	(2): 1995 survey was based on a large sample. Recall and sample size restrict the validity of the builder data.
Ceiling	**R-value**	
Flat	32.7	(2): 1995 survey was based on a large sample. Recall and sample size restrict the validity of the builder data.
Attic	30.9	(2): 1995 survey was based on a large sample. Recall and sample size restrict the validity of the builder data.
Cathedral	26.8 batt+1.2 rigid averaged over all houses	(2): 1995 survey was based on a large sample. Recall and sample size restrict the validity of the builder data.
Infiltration rate	**Air Changes/Hour**	
Natural infiltration rate	0.535	(2): 1995 survey was based on a large sample. No more recent test data were available.

Sources

(1) Estimate from builder survey appeared to be unreasonably high. The value used was estimated from data on efficiencies by ranges provided by BBRS. Average efficiency within each range was estimated based on averages derived from 2000 onsite data.

(2) *Final Report: Characterization of Residential New Construction Building Practices in Gas-Heated Homes in Massachusetts*, XENERGY, 1995.

(3) Weighted values from XENERGY/RISE onsite survey in 2000.

(4) Builder survey on 1997 practices conducted by XENERGY/Atlantic Marketing Research in 2000; 50 builders interviewed. Window U-values were estimated based on detailed data provided in American Soiety of Heating, Refrigerating, and Air Conditioning Engineers *Fundamentals* and matched as closely as possible to the default values in the Massachusetts code.

3 CURRENT BUILDING PRACTICES DATA COLLECTION

Data collection to characterize building practices under the new code consisted of site inspections at newly built single- and two-family homes. A random sample of homes was selected to provide a basis for statistically valid estimation of statewide impacts and code compliance. To control field costs while providing statewide coverage, the site visits were clustered in 30 towns. The sample was designed to provide a total of 220 visits.

This section discusses the sample design approach implemented to select areas in which to collect the onsite data. It also discusses the data collection process.

3.1 SAMPLE DESIGN

The general strategy for the sample design was as follows:

1. Towns were selected with probability proportional to the number of homes built in calendar year 1999.
2. To ensure geographic coverage, the selection of towns was based on a stratified sample, with heating degree-day ranges used as the stratification variable since the code varies with climate.
3. For each town selected, approximately the same number of homes was designated for site visits.
4. Towns with a very small number of permits were excluded from the sample to avoid high field costs per completed unit.

The rationale for this design approach is discussed below, followed by implementation details.

3.1.1 Rationale

This subsection discusses the rationale for each of the steps in the sample design process.

Two-Stage Sampling

Using a simple random sampling approach to select houses for this study would have been very expensive because we would have had to visit each building department to obtain the statistics on new construction permits. To keep sampling costs reasonable, we used a two-stage sampling approach instead. Two-stage sampling is a standard statistical technique using clusters that reduces field costs while maintaining a broadly dispersed sample. The two-stage approach meant that the collection of recruitment contact information was limited to the selected towns and the field visits were geographically concentrated in certain areas, thus reducing costs.

Selecting Towns with Probability Proportional to Permits

The strategy of selecting towns with probability proportional to size (pps) combined with an equal number of visits per selected town meant that every house constructed in 1999 had an equal chance of being in the sample. Within the framework of the two-stage sampling approach, pps sampling gave the most efficient sample allocation possible. That is, we got the best statistical accuracy we could within the constraints of the total sample sizes set.

Stratifying by Heating Degree-Days

There are three general reasons to use a stratified sample.

1. The variability of the parameters differs among the strata: In this case, sampling rates should be higher for the more variable strata to provide the most accurate estimate at the state level.
2. The levels of the parameters to be measured differ among the strata: In this case, the sample will tend to be more efficient (better accuracy for the same total sample size) if the sample sizes within each stratum are fixed, rather than varying as they would with a random draw across the whole population.
3. Particular subgroups are of special interest: In this case, a subjective decision is made to allocate more of the sample to the strata of interest. This reallocation gives better information for the subgroups at the expense of less accuracy for the population as a whole.

The motivation for stratifying by degree-day zones was to ensure that each climate zone had "reasonable" coverage. This intuitive concern corresponds to the reason #2 above; i.e., the quantities to be measured were expected to differ by degree-day zone. By controlling the sample distribution across climate zones, we expected better accuracy than would have been achieved by leaving the sample distribution to chance.

Regardless of whether or how the sample was stratified, it was possible to compare groups with different characteristics in the analysis. In particular, it was possible to make comparisons not only by degree-day zone (used for stratification), but also by town size, volume of new construction, or other town characteristics. The degree-day stratification ensured that particular sample sizes were available by group for these comparisons (reasons #2 and #3 above).[1]

Exclusion of Small Towns

The overall sample design required 7 or 8 site visits per selected town. However, some towns had too few permits to complete even 7 visits. Based on previous work, we estimated that we would be able to visit about half of the sites where we attempted recruitment. We also

[1] Another suggested stratification variable was town size, as measured by the number of 1999 permits. As noted, the systematic sampling approach ensured that small and large towns would be selected with appropriate rates, without requiring explicit stratification by size.

anticipated that the number of permits found would sometimes differ from what the construction count data showed, due to imputations in the data and possible reporting discrepancies.

In towns with a smaller number of targeted visits, the cost per site would be relatively high, in part because there would be fewer opportunities for combining nearby visits on a single day.

For these reasons, all towns for which the construction data indicated fewer than 15 permits were excluded from the sample. There were 116 such towns, accounting for 5.1% of total 1999 permits.

3.1.2 Details of the Sample Implementation

Obtaining Permit Data Counts

Counts of the number of construction permits issued in 1999, by town, for single- and two-family homes were obtained from the Massachusetts Institute for Social and Economic Research (MISER) website. The data were for each of 351 towns in Massachusetts. MISER imputed 1999 totals for towns that had incomplete data.

Stratification by Degree-Days

The cut-points for defining degree-day strata were determined by a statistical procedure known as the Delanius-Hodges method. This method gives the most efficient cut-points to use for stratification on a numeric variable. The method assumes that the total number of strata has been specified.

The method also assumes ideally that the stratification variable (in this case, degree-days) is the key parameter to be measured in the study. In practice, the key parameter of interest is never known (or the sample would be unnecessary). Instead, a related variable is used for stratification. For purpose of setting the cut points for stratification, energy savings were assumed to be roughly linearly related to heating degree-days. Designing optimal cut points for degree-days, therefore, corresponded roughly to developing optimal cut points for stratifying on expected savings.

This procedure gave cut points of 6,200 and 6,400 degree-days. These cut points were calculated after the towns with fewer than 15 permits were deleted from the list. The proportions of permits in the resulting three strata were between 28% and 37% of the statewide totals excluding the small towns. The distribution of permits by town size and degree-day strata is summarized in Table 3-1.

Table 3-1
Distribution of Permits by Town Size and Heating Degree-Days

Stratum	Stratum 1		Stratum 2		Stratum 3		Statewide	
HDD	< 6200		6200 - 6400		> 6400			
# Permits Range	# Permits	% of Stratum	# Permits	% of Stratum	# Permits	% of Stratum	# Permits	% of State
15 - 50	702	16.3%	1424	25.3%	1705	33.6%	3831	25.5%
51 - 100	1277	29.6%	2149	38.1%	1979	39.0%	5405	36.0%
101 - 150	908	21.0%	716	12.7%	729	14.4%	2353	15.7%
151 - 200	355	8.2%	1049	18.6%	169	3.3%	1573	10.5%
201 - 250	462	10.7%	0	0.0%	227	4.5%	689	4.6%
251 - 300	274	6.3%	296	5.3%	260	5.1%	830	5.5%
301 - 350	341	7.9%	0	0.0%		0.0%	341	2.3%
Total	**4319**	**100.0%**	**5634**	**100.0%**	**5069**	**100.0%**	**15022**	**100.0%**
Percent of State		**28.8%**		**37.5%**		**33.7%**		**100.0%**

Probability-Proportional-to-Size Sampling of Towns

The MISER data indicated a total of 15,022 permits were issued in 1999, excluding the small towns. Thirty towns were selected. Pps sampling means that one town was selected for every 501 permits (15,022/30).

The selection of towns was by systematic sample from an ordered list. The effect of the systematic sample was as if we listed all 15,022 permits, grouped together by town, then, starting at a random point in the list, selected every 501st permit and went to the town that permit was in. The towns in the list were sorted first by degree-day stratum, then by size. This approach ensured that the selected sample was spread systematically over degree-day strata and over towns of varying size.

The exact number of towns selected for each degree-day stratum or each size range could vary somewhat depending on the random start point. However, this variation in sample allocation was limited. The number of towns allocated to each degree-day stratum could vary only by 1. Likewise, for any size range within a degree-day stratum, the total allocation to the size-degree-day group could vary randomly only by 1. Across the state as a whole, the allocation to a size group could vary by up to 3, allowing for variation by 1 within each of the three degree-day strata.

Table 3-2 shows for each stratum the expected number of towns selected (that is, the average over all possible samples) and the minimum and maximum possible with the systematic sampling approach described. Table 3-3shows the same information by town size range.

Table 3-2
Possible Town Sample Allocation by Degree-Day Stratum

Degree-Day Stratum	# Towns	Total # Permits	% permits	Number of Towns Selected: Expected	Minimum	Maximum
1	55	4319	28.8%	8.6	8	9
2	84	5634	37.5%	11.3	11	12
3	96	5069	33.7%	10.1	10	11
Total	**235**	**15022**	**100.0%**	**30**	**30**	**30**

Table 3-3
Possible Town Sample Allocation by Size Range

Permits per Town	# Towns	Total # Permits	% Permits	Number of Towns Selected: Expected	Minimum	Maximum
0 - 14	116	802	-	-	-	-
15 - 50	122	3831	25.5%	7.65	6.00	9.00
51 - 100	78	5405	36.0%	10.79	9.00	12.00
101 - 150	19	2353	15.7%	4.70	3.00	6.00
151 - 200	9	1573	10.5%	3.14	2.00	5.00
201 - 250	3	689	4.6%	1.38	0.00	2.00
251 - 300	3	830	5.5%	1.66	0.00	3.00
301 - 350	1	341	2.3%	0.68	0.00	1.00
Total	235	15022	100%	30	30	30

The specific procedures followed to implement the systematic sample were as follows:

1. Sort the towns by degree-day sampling stratum, then by size (number of permits). The selection probability for each town was the town's fraction of statewide permits: $p_t = N_t/N_{TOT}$
2. The interval from 0 to 1 was divided into 235 segments. Each segment in order corresponded to a town in the sorted list and had length equal to the town's selection probability $p_{t.}$
3. A random number U between 0 and 1/30 was selected, from a uniform distribution.
4. The 30 numbers d_k were calculated as $d_k = U + k/30$, k = 0,2,…,29
5. Each town corresponding to a segment that included one of the draws d_k was selected for the sample.

Assigning the Number of Visits Per Selected Town

Typical pps sampling involves selection of clusters (for this study, towns) with probability proportional to the number of units (permits), then selecting an equal number of units within each selected cluster. With this approach, each permit in the state has an equal chance of being included in the sample.

The total number of completes desired (220) divided by the number of towns visited (30) equaled 7⅓, but we had to select an integral number of houses to visit in each town. We developed an approach to determine randomly whether 7 or 8 houses would be selected in each town. Once the 30 towns were selected, the list of selected towns was scrambled, with 8 visits assigned to the first 10 in the scrambled list and 7 to the remainder. This method meant that the expected number of visits per town was 7⅓, for all towns, and all units had an equal overall probability of being included in the sample.

Systematic Sample of Permits within Towns

The selection of permits within towns was accomplished by going to the town records, selecting a random start point, then taking every n^{th} permit in order from the records. The number of records to be selected was greater than the targeted number of visits for each town, since not all recruited sites were expected to agree to the visit. To provide the necessary over-sample, three times the target number of completes were selected where possible, or all permits if the total was less than three times the target.

The procedure for the selection from the permit records was as follows:

1. Determine the total number of records N_t for the town.
2. Determine the sampling interval k as $N_t/(3n_t)$, where n_t is the targeted sample size (30). Round the interval to the nearest integer. If the interval calculated is less than one, select all records.
3. Select a random starting point s on the interval 1, k, using a table of random numbers.
4. Select the s^{th} permit and every k^{th} permit thereafter.

3.1.3 Sample Selected and Achieved

Table 3-4 shows the towns selected for the sample, the number of visits targeted for each, and the number of visits actually completed. Information provided for each selected town includes the following.

Heating Degree-Day Stratum: Degree-day strata are
1) < 6200
2) 6200- 6400
3) > 6400.

Number of permits: The number of 1- and 2-family permits for new construction in 1999, based on the MISER data.

Percent of permits: The number of 1- and 2-family permits in the town as a percent of the statewide total. This statewide total excludes towns with fewer than 15 permits.

Selection probability: The probability this town had of being included in the sample. Thirty towns were selected with probability proportional to the number of permits. Thus, the selection probability for each town was 30 times the percent of permits in that town.

Target visits: The target number of visits targeted to be completed, either 7 or 8.

Completed Visits: The number of visits actually completed.

Table 3-4
Sample Selected

HDD Stratum	Town Name	Number of Permits	Percent of Permits	Selection Probability	Target Visits	Completed Visits
(1)	HINGHAM	24	0.16%	4.79%	8	3
	REVERE	37	0.25%	7.39%	8	3
< 6200	NEEDHAM	65	0.43%	12.98%	8	5
	BREWSTER	119	0.79%	23.77%	7	7
	SANDWICH	126	0.84%	25.16%	7	6
	DARTMOUTH	143	0.95%	28.56%	8	8
	BOSTON	188	1.25%	37.54%	7	5
	NANTUCKET	225	1.50%	44.93%	7	2
	MASHPEE	341	2.27%	68.10%	7	7
	STRATUM 1 TOTAL				67	46
(2)	DEDHAM	30	0.20%	5.99%	7	7
	DANVERS	31	0.21%	6.19%	7	3
6200	BOXFORD	34	0.23%	6.79%	7	5
to	GARDNER	46	0.31%	9.19%	7	7
6400	EASTON	62	0.41%	12.38%	7	7
	RAYNHAM	66	0.44%	13.18%	8	7
	TEWKSBURY	98	0.65%	19.57%	7	7
	SOUTHBOROUGH	105	0.70%	20.97%	7	7
	ATTLEBORO	164	1.09%	32.75%	7	7
	HOPKINGTON	182	1.21%	36.35%	7	7
	PLYMOUTH	296	1.97%	59.11%	7	7
	STRATUM 2 TOTAL				78	71
(3)	HADLEY	16	0.11%	3.20%	8	8
	NORFOLK	40	0.27%	7.99%	7	6
> 6400	EAST LONGMEADOW	41	0.27%	8.19%	8	8
	BELLINGHAM	63	0.42%	12.58%	8	8
	LEXINGTON	63	0.42%	12.58%	8	7
	NORTHBRIDGE	64	0.43%	12.78%	7	7
	CHARLTON	79	0.53%	15.78%	8	8
	WESTFIELD	121	0.81%	24.16%	7	7
	NEWBURYPORT	121	0.81%	24.16%	7	4
	UXBRIDGE	138	0.92%	27.56%	7	6
	STRATUM 3 TOTAL				75	69
TOTAL					**220**	**186**

Recruitment turned out to be more challenging for this project than for similar studies conducted in the past. As a result, the decision was made to terminate data collection prior to completing the target of 220 visits. To ensure adequate data for analysis, including variance estimation, data collection was not stopped for a town unless at least two visits were completed in the town. We were able to collect data on a total of 186 houses, which still provided an adequate sample sizes for statistical purposes.

3.2 DATA COLLECTION

This subsection describes the process used to collect the data to document current construction practices.

3.2.1 Building Department Data

The BBRS provided names of building officials and their office phone numbers.[2] The BBRS sent a letter to each building official of the 30 towns in the sample requesting their cooperation in supplying access and information. The BBRS also provided a letter of introduction, addressed to each building official, to be carried by field staff and presented on arrival at the town's building office.

A single member of our team was designated to perform data collection from the town offices. He called each official in advance of his visit to introduce himself and describe what he would be doing. He visited every one of the town offices and was often accompanied by an assistant. The tasks at each town office are described briefly below:

- Identify survey sample sites: Identify new home construction permits applied for since the energy code change was implemented. Begin pulling files from among this group at random. Identify those that had occupancy dates indicating the work was completed. Continue to gather files until 30 completed homes from the time period had been identified.
- Record building file data: Record the builder's name, address, and phone number; record permit date, occupancy date, and site address. Photocopy the MAS*check* or Prescriptive Package data sheets from the file (if any). Note the presence in the building file of supporting information including shell R-values, window and door U-values, heating equipment Annual Fuel Utilization Efficiency (AFUE), and air conditioner Seasonal Energy Efficiency Ratio (SEER) (if any).
- Identify present homeowner: Most new houses are sold after the occupancy permit is issued; in these cases the building officials' records have no information on the homeowner. In these cases, the field data collection person would leave the building official's office and move on to the tax assessor's office. In some towns this would be at

[2] David Weitz at BBRS provided this information. The actual data collection and database entry was performed by RISE, Inc. under contract to XENERGY.

a different location. Although one would think that owner information would be up to date and easy to come by at assessors' offices, this was often not the case. If we were unable to get the needed owner information we would visit the registry of deeds, which in Massachusetts is a county function requiring travel to other towns. If we were still unable to identify the owners of all 30 files, we would return to the building official's office to collect a still larger sample and continue until the sufficient number of owners had been identified. We then attempted to identify owners' home phone numbers through the phone book and the Internet.

- Contact homeowners to gain study participation: We gained homeowner participation through a combination of mailings, phone calls, and even knocking on the doors of identified homes.

3.2.2 Home Onsite Survey Data

We conducted site visits to the selected homes between July and December 2000. Four individuals were assigned to perform this fieldwork. Visits were performed by prior appointment only. The majority of the visits occurred during normal working hours, but a fair number were performed during evenings and on Saturdays to achieve a sufficient participation sample size for the study's requirements. Due to the volume of information collection required and the complexity of many of the houses, typically no more than two visits per day, per person could be completed.

Building components were checked through visual inspection and measurement. Several procedures were used to collect the data for each home: attics were accessed and thoroughly inspected; walls were checked with wire probes at the edge of electrical boxes; windows were checked for the presence of low-emissivity (low-E) coatings with specialized meters (EDTM, Inc., Model ETEKT+); equipment nameplate data were recorded; blower doors were operated to identify building air exchange rates (Minneapolis Blower Door); and ducts were visually inspected.

Vapor barrier presence was determined when probing wall cavities. In a large number of these new houses there was some point at which the barrier could be viewed (e.g., beneath the hot tub, at the wall of a walkout unfinished basement, at attic common walls, etc.). We could not, of course, determine barrier uniformity throughout—if what we could see was uniform, we gave the benefit of the doubt that the rest was installed properly.

Insulation levels were determined based on either how much of the cavity depth was filled or a stamped R-value, if observable. Often it was the case that an unfinished walkout basement wall was framed in the same manner as the rest of the house and had visible stamped R-values, or we could see stamped R-values within an exterior wall accessible from the attic (such as the gable wall adjoining a scissors truss slope where there is not a top plate). In these types of locations, we would look to see whether a higher density insulation was present than we had assumed based on cavity depth. For example, we might see R-13 stamped where we had been assuming a default 3.5" wall insulation R-value of R-11. We identified blown insulation wherever it was present, and its R-value was determined through standard defaults based on its depth.

The blower door tests were conducted using the protocol specified by the equipment manufacturer.

In addition to data collection for the BBRS compliance study, lighting, appliance and duct air tightness data were gathered for a companion study for the Joint Management Committee (JMC).3 In 22 cases the air tightness of duct systems was measured through the use of pressurization equipment (Minneapolis Duct Blaster). This duct system leakage to the outside of the house was estimated by pressurizing the house to 25 Pascals with a blower door and then pressurizing the duct system with a Duct Blaster until a zero pressure difference existed between the duct system and the inside of the house. The leakage under these conditions was an estimate of the leakage outside the conditioned space. This was compared to the duct system flow with the duct system alone pressurized to 25 Pascals.

Homeowners were interviewed to determine temperature control settings, hours of use, etc. An incentive was paid to each homeowner as a way of thanking them for their time and participation. No written report of any kind was left with a homeowner.

A data collection form was used to enter the onsite data and data extracted from compliance documents at the building departments (see Appendix A). It was possible to enter up to 1,258 values for each house; typically, about half this number was entered for any given house because many data types did not apply to all houses. All the survey data collected onsite then were entered into a spreadsheet and prepared for analysis. Table 3-5 summarizes the categories of data collected.

The detailed data collected for each of the envelope segments were aggregated to prepare the inputs for MAS*check* runs. This process simplified the compliance analysis that was done. These data for each house were input into MAS*check* and the resulting UA was compared with the required UA calculated by the compliance software. The detailed data also were used to develop inputs for DOE2 simulation model runs that we used to estimate the energy consumption of each building.

[3] The Joint Management Committee (JMC) is a consortium of electric and gas utility companies who sponsor the Energy Star Homes program in Massachusetts and other parts of New England. The sponsoring JMC utilities provide funding for services and rebates to support energy efficiency in residential new construction. Conservation Services Group (CSG) coordinates and administers JMC activities, including Energy Star Home program implementation and monthly JMC meetings.

Table 3-5
Summary of Data Collected for Each House

Data Category	Types of Data Collected
General Information	• Owner name, address • Completion/occupancy dates • Builder information
General Building Description	• Home type • Volume and floor area • Number of floors and bedrooms • Basement type • Orientation
Energy Code Compliance Information	• Compliance method
Prescriptive Package Compliance Data (if compliance using prescriptive package option)	• Climate zone • Component requirements • Verification of compliance
MAS*check* Compliance Information	• Data in MAS*check* form filed by builder and data collected onsite • Areas/perimeters for multiple sections of ceilings, walls, basements, and floor and multiple doors, windows, and skylights • Insulation R-values for all components and sections • Heating and cooling equipment type and efficiencies • Calculated and required UA • Assessments of whether component and equipment actual characteristics differ from builder data • Assessment of whether home complies
Other Compliance Information	• Assessment of compliance with air infiltration control, duct sealing and insulation, pipe insulation, and other requirements
Detailed Building Characteristics	• Details on up to 10 segments of each building envelope component • Areas/perimeters, orientation, location • Insulation R-values • Framing spacing • Window and skylight areas, orientation, frame type, glazing type, U-value • Door characteristics • Heating/cooling system type, heating fuel, capacity, efficiency, make, controls
Operating and Controls Characteristics	• Occupant heating/cooling setpoints • Thermostat type and number
Water Heater Characteristics	• Fuel type, efficiency, size
Air Infiltration/Ventilation Characteristics	• Blower door measured air infiltration rate

Data Category	Types of Data Collected
	• Characteristics of multiple ventilation systems
Duct System Characteristics	• Measured duct flow and outside leakage (subset of houses) • Duct system area, R-value, condition
Internal Gain Sources	• Numbers of appliances
Detailed Appliance and Lighting Characteristics	• Refrigerators, room air conditioners, dishwashers, clothes washers • Manufacturer, size, vintage • Lighting fixture location, wattage, control type

4 BUILDING DATA ANALYSIS APPROACH

This section describes the approaches used to analyze the building data compiled for this study. It discusses the onsite current construction practices data analysis, the code compliance analysis approach, and the approach used to analyze the energy and emissions impacts of the new code.

In almost all cases, we conducted the analyses using values weighted according to our sampling procedure.[1] This allowed the estimates produced to be used as population estimates.

4.1 CURRENT CONSTRUCTION PRACTICE

Very detailed characteristics were documented for each of the 186 houses for which onsite data were collected. To simplify the analysis, we relied primarily on the data that we entered into the MAS*check* analysis for each building. These characteristic data were built up from the detailed data collected on site for each building component and piece of equipment.

We analyzed these data by calculating the mean value and standard error of the mean for each of the quantitative building characteristics. For categorical data, we calculated the percent of houses that fell into different categories. In some cases, we documented the distribution of the values observed in the onsite surveys.

4.2 CODE COMPLIANCE

In all cases, we determined basic code compliance by running MAS*check* for each building based on the observed building characteristics collected on site. MAS*check* calculated and provided the maximum thermal transmittance (UA) allowed by the code and the UA calculated for the building as built ("Your Home" UA). The compliance software adjusted the allowable UA based on the efficiency of the heating equipment, with more efficient heating systems allowing higher building UAs. If the calculated UA was equal to or less than the maximum allowable value, we documented in the database that the building complied with the code. These data allowed us to determine the proportion of houses that met the code and to document the distribution of the house UAs relative to the required level. The onsite surveys also documented whether the house met other general code requirements (Section 780 CMR J4.0 GENERAL REQUIREMENTS in the code) including whether infiltration mitigation measures were installed properly, duct systems were sealed and insulated adequately, etc. We calculated the percent of houses that met and did not meet these requirements.

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[1] In a few cases, we calculated results without weighting the observations because of the complexity of trying to apply the weighting rigorously on subsets of data. We tested the validity of using this approach and found that the weighted and unweighted results differed by less than 1%. The text notes where the reported results were not based on the sample weights.

In cases where the builder had submitted a MAS*check* run printout, we also documented whether the onsite values were substantially different from the values reported on the printout. The onsite surveyors noted whether the areas/perimeters, insulation levels, or glazing/door U-values differed from the submitted values by more than 10% and whether the heating equipment AFUE differed by more than 5% from the reported value. We analyzed these data by determining how many houses had values recorded on site that exceeded these thresholds.

We also conducted two other analyses related to compliance. One was analysis of the measured duct flow rates and duct losses outside conditioned space. We calculated the average percent losses for the 22 houses where these measurements were taken. The second was an analysis of the sizing of heating and cooling equipment. We used the simulation model (described in Section 4.3) to estimate the peak heating and cooling loads. These loads were then compared to the capacity of the equipment and the amount of oversizing or undersizing was determined.

4.3 ENERGY AND EMISSIONS IMPACTS

This subsection briefly discusses the energy and energy savings analyses and the emissions analyses that we conducted.

4.3.1 Energy and Energy Savings

We analyzed the effects of the code on energy use by running an energy use simulation of each building. We used the DOE-2 simulation model for these analyses.[2]

For each building, we used the onsite survey data to create detailed DOE-2 building models. DOE-2 is a widely used and accepted building energy analysis program that can predict the energy use for all types of buildings. DOE-2 uses a description of the building layout, construction details, end-use and space conditioning systems (lighting, HVAC, etc.) provided by the user, along with weather data, to perform an hourly simulation of the building and to estimate utility bills.

We extracted building shell, equipment, and operating characteristics from the database and wrote them to an electronic file format compatible with the simulation program. A multi-zone building model was utilized, featuring the main house space along with optional basement, attic, and garage spaces. Each model was assigned an appropriate weather file and simulated for a "typical year." Results of these simulations were annual heating and cooling energy use for the 186 "as-built" homes.

We estimated energy savings for electricity, natural gas, oil, and propane for three end uses—space cooling, space heating, and water heating. "Pre-period" heating and cooling energy usage were determined by replacing the onsite survey values for insulation levels and equipment efficiency with values determined from the other studies identified in the discussion of baseline values in Section 2. The building models were recreated with these pre-period values and were

[2] Paul Reeves of Partnership for Resource Conservation conducted these analyses.

used to determine the annual heating and cooling energy requirements for the 186 “pre-period” homes. A comparison of the pre-period and “as-built” energy estimates led to an energy savings value for each audited home.

Savings were calculated per house and per square foot and the mean savings and standard error of the mean for the population were estimated. For some houses, the estimated savings were negative (i.e., the energy use was estimated to increase relative to baseline practices) for one or more end uses or the house as a whole. In some cases, this was due to building practices that did not meet code for a given house. In the case of certain end uses, it was due to assumptions about the baseline practices that might have overstated the efficiency of measures or equipment that would have been installed in *that specific house* prior to the code revisions. For example, our baseline air conditioner efficiency level was based on a 1995 average, which was slightly higher than the minimum level required by standards; houses that had air conditioners just meeting the minimum efficiency level could produce a negative energy savings when referenced to this baseline value, even though the builder probably would have installed the minimum efficiency air conditioner prior to the code revisions as well. On the average, however, these biases in the estimates would have been cancelled out by biases in the other direction.

Separate analysis runs utilized DOE-2’s design day features to size the heating and cooling systems. Design ambient temperatures were taken from the Massachusetts State Building Code; other design conditions followed Manual J recommendations. The values determined from the DOE-2 design calculations were the peak heating and cooling requirements under the design-day conditions.

4.3.2 Emissions

We calculated the annual emissions reductions on a per house basis. The analysis was straightforward. Emissions rates per unit of energy type used were multiplied by the amount of energy saved. The emissions factors we used are shown in Table 4-1.

Table 4-1
Emissions Factors

Energy Type	SO_x	NO_x	CO_2
Electricity	9.3 Lbs/MWh	2.6 Lbs/MWh	1,484 Lbs/MWh
Natural Gas	0.0 Lbs/MMBtu	0.1049 Lbs/MMBtu	109.99 Lbs/MMBtu
Oil	0.3131 Lbs/MMBtu	0.1330 Lbs/MMBtu	168.59 Lbs/MMBtu
Propane	0.001 Lbs/MMBtu	0.1648 Lbs/MMBtu	127.5 Lbs/MMBtu
Sources: Electricity values are from ISO New England, Inc., September 1998. *1997 Marginal Emission Rate Analysis for the NEPOOL Environmental Planning Committee.* Natural gas and oil values are from the Lawrence Berkeley National Laboratory. Propane values are from the U.S. Department of Energy.			

XENERGY

4.4 SEGMENTATION ANALYSIS

To examine factors that might be related to differences in construction practices, code compliance, energy and energy savings, and emissions impacts, we calculated the results for several different segmentations. These included the following:

- Climate zones: <6,200 heating degree-days (HDD), 6,200 to 6,400 HDD, and > 6,400 HDD[3]
- House selling price: <$200,000, $200,000 to $400,000, and >$400,000
- Heating fuel type: oil, natural gas, and propane (no houses in our sample were heated with electricity)
- Heating system type: forced air, boiler, and hydro-air
- Building official activity level: 5 to 21, 29 to 64, and 91 to 171 permits per official per year
- Code compliance: whether the house met the code or not

We calculated the means (and standard errors) of all parameters and variables in the onsite database for each of these segment groups and the segments defined within them.

[3] These were the climate zone definitions used for designing our data collection stratification.

5 CODE COMPLIANCE AND IMPACTS

This section provides our major findings regarding code compliance, code impacts, and construction characteristics of homes built under the new code. The first subsection presents findings regarding compliance with the code, based on our analysis of the onsite data. The second section provides estimates of the energy and emissions impacts of the code. The final subsection summarizes the construction characteristics of new homes built under the code and summarizes the differences between the average current practice and baseline values.

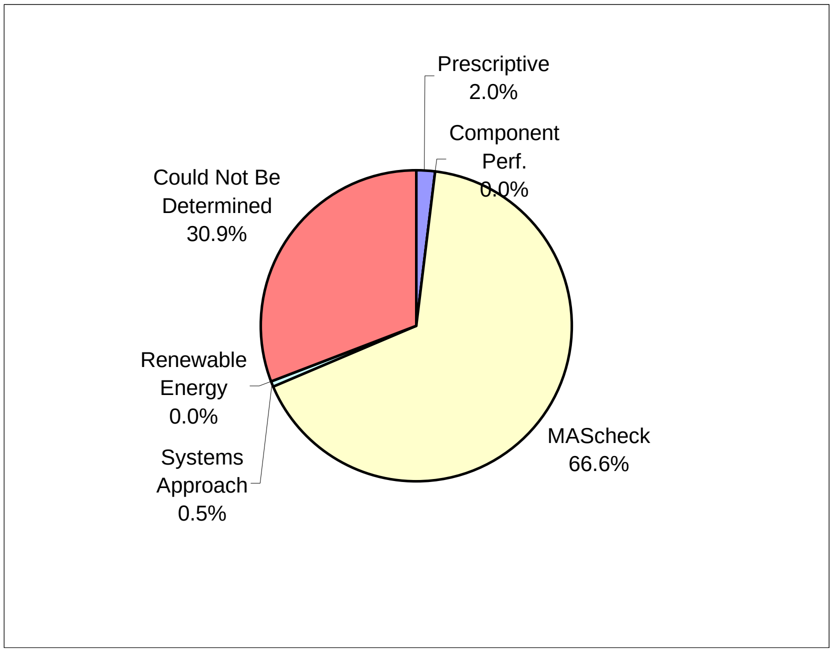
In most cases, the results have been weighted to provide a population estimate from our sample of onsite data. We indicate those cases where the data have not been weighted.

5.1 CODE COMPLIANCE

This subsection presents the key findings of this study—the code compliance results. It first summarizes the types of methods used to demonstrate compliance. It then presents the overall compliance findings. These are followed by results for segments of interest. Finally, a discussion of general compliance and enforcement issues and reasons for noncompliance are presented.

Figure 5-1 shows our estimates of the percentage of houses in the population that used different methods to demonstrate compliance with the Massachusetts energy code. By far the most common method used was the MAS*check* approach—two-thirds of the houses used this method. In almost one-third of the cases we surveyed, however, we were unable to determine the actual compliance method used. There were no MAS*check* forms or other compliance documentation in the files for these houses that could be used to determine the compliance method. Only 2% of the houses relied on the prescriptive packages method. Less than 1% used the systems approach. None of the houses used the component performance or renewable energy approaches.

Figure 5-1
Frequency of Different Compliance Methods



5.1.1 Compliance Results

Based on the MAS*check* runs that we conducted for all houses, we estimated for the population of new houses that 46.4% complied with the new code requirements in terms of their overall UA. Figure 5-2 shows the compliance data in terms of the ratio of actual UA to the UA required to meet the code—values equal to or less than 1.0 indicate compliance.[1] The figure displays the distribution of houses by ranges of the UA ratio and the cumulative percentage of houses with a UA ratio less than the value shown. Although over half the houses had UAs in excess of the allowable level, only 20% were more than 10% above the allowed value; only 8% exceeded the allowed value by more than 20%. On the other hand, about 15% were at least 10% more efficient than required by the code.

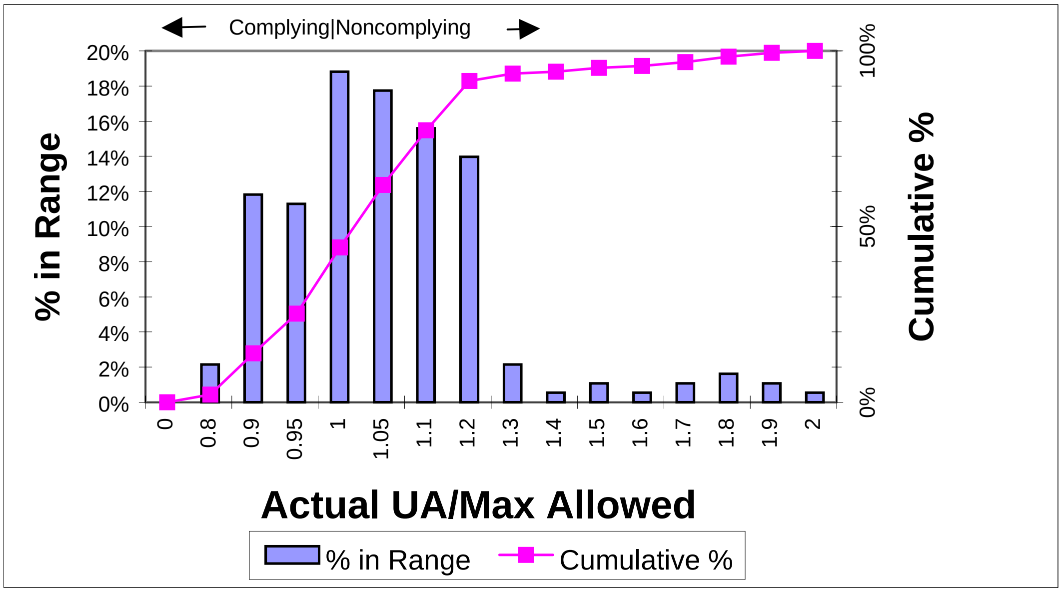
Only three houses were determined to have used the prescriptive package approach for compliance. Only one of these actually complied. One house that did not pass with this method failed because the window U-value was higher than permitted and the other did not meet the code requirements in all wall segments.

The fact that we were unable to determine the compliance method for a large proportion of houses from the permit documentation raised the question of whether these houses were less likely to comply. Our analysis of compliance, however, showed that adequate documentation was lacking in the same proportion for both complying and noncomplying houses.

[1] The data shown in the figure were based on unweighted results.

These compliance results were disappointing, but they were fairly consistent with compliance findings conducted on codes in other states in recent years. One recent study, conducted in Arkansas, found that statewide only 55% passed the energy code.[2] Although this share was higher than in Massachusetts, the efficiency requirements in Arkansas were considerably lower.

Figure 5-2
Code Compliance Distribution



Several specific code compliance issues were addressed in the onsite surveys. Three focused on how close specific onsite measures were to the values documented in the original compliance report. Table 5-1 shows that the component areas or perimeters were the most likely to differ by at least 10% from the values in the original compliance documentation—only about one-fourth

Table 5-1
Comparison of Actual and Compliance Report Values

Measure	% of Homes with Actual Value within 10% of Compliance Report
Areas/perimeters	22.5%
Insulation levels	67.5%
Glazing/door U-values	56.0%

differed by less than 10%. About two-thirds of the houses had insulation levels and 56% had glazing or door U-values that differed by less than 10%. Although the discrepancies between the

[2] Brown, Evan C. 1999. *Energy Performance Evaluation of New Homes in Arkansas.* Arkansas Energy Office.

original compliance documents and the as-built characteristics did not necessarily imply that the houses were not built to code, their prevalence suggested that the original energy-code compliance documents could not be relied upon in most cases to verify compliance of the actual house. In only about one-fourth of the towns visited was there evidence that the MAS*check* documentation was taken to the field and the analysis was rerun if changes were found in the field.

Compliance with additional energy code general requirements is summarized in Table 5-2. The most common deficiencies were for the proper installation of air infiltration measures and adequate sealing of ducts. The code's infiltration requirements that were checked thoroughly were the following:

- Joints, penetration, and all other such openings in the building envelope that are sources of air leakage must be sealed.
- Recessed lighting must be installed either with no penetrations between the inside and outside of the fixture and sealed or gasketed or the fixture must be tested and labeled according to Standard ASTM E 283.

Compliance with these requirements was determined primarily visually. Looking down from within attics it was possible that sealants applied from below during framing were not entirely visible; the field inspectors gave the benefit of the doubt if any sealant was observed (for example foam visible around pipes but not visible at tight wire holes was assumed to be on those wires as well.) The overall determination of proper sealing was made on an all-or-nothing basis—e.g., if wiring and plumbing penetrations were sealed but the attic door was not, then the site "failed" this verification check.

Table 5-2
Compliance with General Code Requirements

Requirement	% of Homes Meeting Requirement
Air infiltration measures installed properly	16.5%
Duct systems sealed adequately	19.0%
Duct systems outside conditioned space fully insulated	76.2%
HVAC hot water pipes fully insulated	67.9%
Each HVAC system has own thermostat	99% of all houses 97% of houses with more than one heating system
Each HVAC zone has means to restrict input	89%
Vapor retarder present	69%

In the leakier houses, a common problem was unsealed kneewall transitions. In modular houses, overhangs were often not sealed properly (as well as insulated) and the center gap in the attic, where modules are connected in the field, was often not sealed.

About 51% of the houses had forced-air heating systems, and serious problems were found in the quality of duct sealing in about 80% of these houses. Examples of problems identified in the onsite visits included the following:

- Panned framing returns were installed with wrinkles in the sheet metal that caused gaps between the metal and the joist and they were left unsealed.
- Panned returns were installed that used the uninsulated floor of a vented attic as a duct.
- Tab collars were used to attach round ducts to the main duct plenum and they were often loose and leaky.
- Mastic or other sealants were used very rarely to seal the ducts.

Figures 5-3 through 5-5 illustrate some of the common problems associated with leaky air distribution systems that were identified during the onsite surveys. Figure 5-3 shows a large leakage area in the tape sealing the air handler that's located in an attic.

Figure 5-3
Poor Sealing at Air Handler Fan

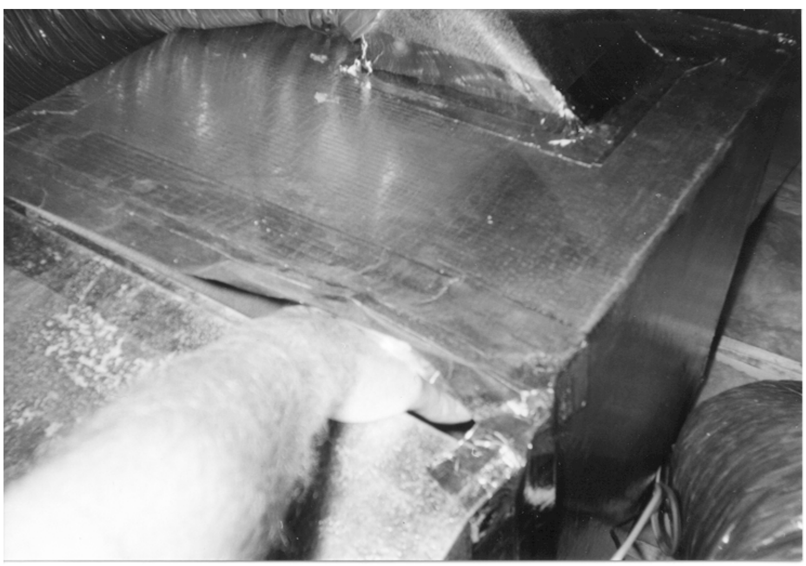


Figure 5-4 shows a typical air distribution system configuration that combines components of different sizes, types, and shapes, thus making proper sealing difficult. This system combines ductboard, flex duct, and tin and the tin component is uninsulated.

Figure 5-4
Mismatched Air Distribution System Components

Figure 5-5 shows another example of mismatched components. The view is into a joist bay and at the end of this bay is a round insulated flex duct stuffed into the joist bay. From within the attic a hand could easily reach into the joist bay without having to move the flex duct—a pencil was placed from above in this manner. The bay had a non-functional blocker at the end. Beyond the blocker was ceiling insulation in an unfloored portion of the attic. This return could easily pull as much air from the attic as from the house.

Figure 5-5
Round Duct in a Rectangular Space

Even though lack of proper duct sealing was a common problem, insulation of ducts outside conditioned space was properly done in over three-fourths of the houses.

Although duct leakage tests were not required by the code, we conducted duct air flow tests on a subset of houses with furnaces to obtain a measure of how leaky typical duct systems were. These results are reported in the discussion of housing characteristics presented later.

In other compliance areas, we found that about 70% of the houses with boilers had pipes that were properly insulated. The appropriate number of thermostats was present in almost all the houses and the zonal controls were appropriate in almost 90% of the houses. Vapor retarders were properly installed in almost 70% of the houses.

The final compliance area that we investigated was the sizing of heating and cooling equipment. The code requires that the rated output capacity of the heating/cooling system at design conditions not be greater than 125% of the design load calculated in accordance with techniques recommended in the ASHRAE Handbook of Fundamentals or the Air Conditioning Contractors Association's Manual "J", or other approved procedure. To conduct an analysis of equipment sizing within the scope of our study, we used our DOE-2 analyses (described later in discussion of energy savings analysis) and the design conditions specified by the code to estimate the maximum heating and cooling load for each house and compared that with the rated capacity of the installed equipment. Although the DOE-2 simulations would not be expected to produce exactly the same results as the Manual J methodology, we believe that because of the fundamental approach used by DOE-2 they are sufficiently close to provide reliable findings.

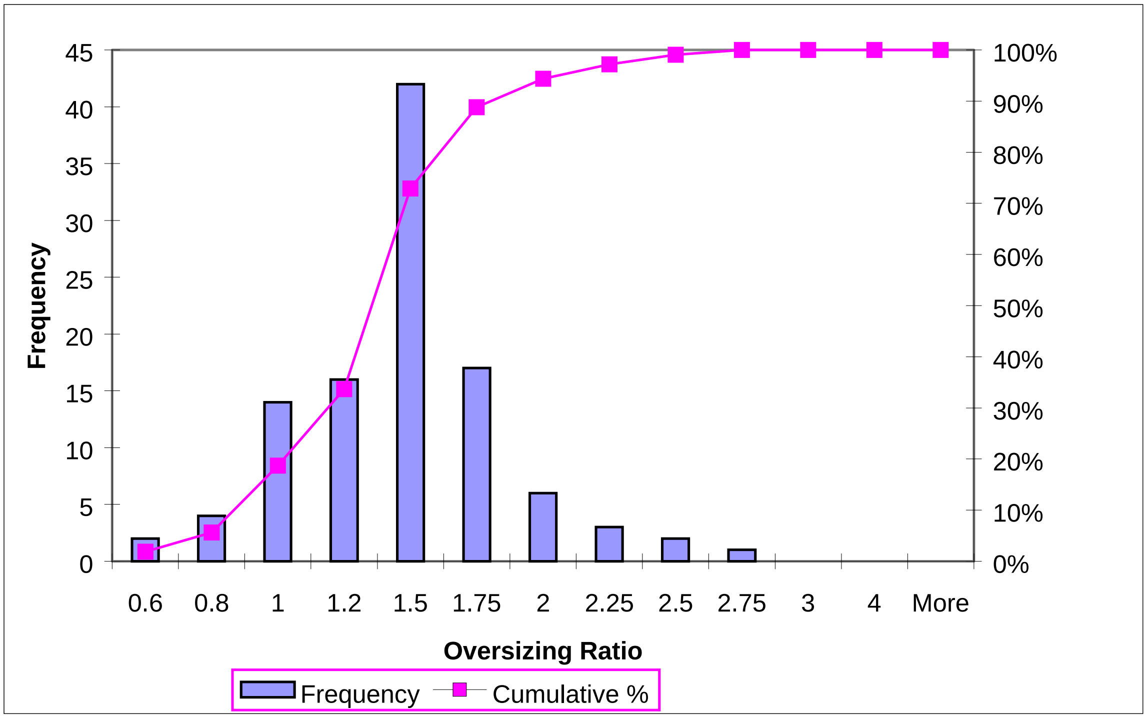
We found that on the average the system capacity for heating systems exceeded the maximum capacity required to maintain design conditions by 69%; i.e., the average system was rated at a heating capacity 69% larger than would be required at design peak conditions.[3] For cooling systems, however, the installed systems on the average had only about 10% more capacity than was required to meet maximum design demand. Since the code permits the systems to exceed the maximum design condition requirements by 25%, code compliance had to be determined by how the capacity compared to the allowable sizing.

Figure 5-6 shows the distribution of the heating system capacities relative to the level permitted by the code (i.e., 25% over the design conditions load). Clearly, a large proportion of the systems were oversized. The average oversizing relative to the level allowed by the code was 35%. Only 19% of the heating systems met the code sizing requirement. Systems were sized most frequently to be about 50% larger than permitted by the code.

Although these results showed that heating systems were commonly oversized, this was not inconsistent with findings from other recent studies. For example, the study of Arkansas code compliance cited earlier showed that the average system was 94% larger than required based on the Manual J methodology (which was estimated to produce sizing 10-20% larger than the estimated maximum heating load). Nearly 50% of the houses in the Arkansas study were sized to put out more than twice the heat required based on the Manual J methodology estimate.

[3] These values were calculated excluding systems that provided both space and water heating. The code is not completely clear about sizing restrictions on such systems. For example, Section J4.4.2.1.1 indicates that equipment designed for "standby purposes" is excluded from the sizing requirement, but the code does not explicitly categorize systems that provide water heating as meeting "standby purposes." Section J4.5.2.3 prohibits water-heating systems that are dependent on year-round operation of space heating boilers, with a few exceptions (such as a rated capacity less than 150,000 Btu), but it does not mention forced-air systems that also provide heated water. By excluding all combined systems from our oversizing calculations, the oversizing frequency we estimated is a lower bound estimate.

Figure 5-6
Distribution of Heating System Sizing Relative to Code Requirements



The arguments on how oversizing increases energy consumption mainly depend on the inefficiencies associated with cycling equipment that probably would be more efficient if run for longer periods of time. The literature on the effects of residential heating and cooling equipment oversizing, however, does not provide unambiguous or extensively researched results. For air conditioners, one recent report cites literature studies that suggest that oversizing air conditioners by 50% can increase energy use as little as 2% or as much as 10%.[4] We were unable to find much literature that dealt with the energy penalty from oversizing heating equipment. In addition to an energy consumption penalty, equipment that is larger than necessary is likely to have a first-cost penalty as well (although the amount depends significantly on pricing practices). The equipment sizing findings can be summarized as follows:

- Compared to code requirements, the heating equipment in new Massachusetts's homes was oversized by a substantial amount, on the average.
- Air conditioning equipment, however, appeared to be sized very close to the design cooling load and within the limits allowed by the code.
- Based on the limited literature available, the oversizing of heating equipment was consistent with common practice in other states.

[4] Neme, C., J. Proctor, and S. Nadel. 1999. "Energy Savings Potential from Addressing Residential Air Conditioner and Heat Pump Installation Problems." American Council for Energy-Efficient Economy, Washington, D.C.

- More research is needed to determine what the energy consumption and first-cost effects are of oversizing heating equipment.

5.1.2 Compliance Rates by Segment

We investigated compliance rates across several different segments because of expected correlations or relationships between compliance and other factors. These investigations allowed us to assess different hypotheses about factors that might affect the degree of enforcement and compliance, and the information from these analyses could be useful in future efforts related to implementing the code. Appendix C summarizes the segmentation results.

Climate Zones

One factor we examined was climate. The code requires more efficient features in houses sited in areas with more severe winter heating requirements; thus, higher insulation levels, more efficient windows, etc. have to be installed to meet the code in colder areas. One hypothesis is that it would be more difficult and costly to meet the code in the colder areas so the compliance rate might be less in these areas.

The compliance rates across three different climate regions of Massachusetts, as defined by heating degree-days (HDD), are presented in Table 5-3.[5] The expected trend, if the proposed hypothesis were true, would be a declining compliance percentage going from one climate zone to a colder one. The data, however, did not exhibit a consistent trend.

To statistically test for differences, we compared the ratio of the actual UA to the maximum allowable UA (see Figure 5-2) for each house by climate zone. We did not find a statistically significant difference between the mean values for the two milder zones. However, the mean value for the coldest region was different from the means for the other two regions at less than the 0.05 level. This provided strong evidence that the ratio of actual UA to allowable UA was considerably higher in the coldest zone compared to the milder zones and confirmed that noncompliance was a more significant problem in the coldest areas.

Table 5-3
Compliance Rates by Climate Zone

	<6,200 HDD	6,200 to 6,400 HDD	>6,400 HDD
Percent Meeting Code	49.4%	54.4%	34.9%
Standard Error	6.4%	4.5%	7.2%

[5] These are the same climate zone definitions we used to develop our samples, as described in Section 3, and do not coincide with those used to define the code requirements.

House Price

One might anticipate that more expensive houses would be more likely to comply with energy codes because more investment was made in general quality improvements. We examined this by comparing compliance rates among different purchase price ranges. Table 5-4 shows the percentage of houses that complied by price range.

Instead of the postulated relationship, the data suggested that compliance declined with higher house purchase prices. To test whether the variation in house price was statistically significant, we applied a chi squared test based on the percent of houses meeting code in each price category, and the (weighted) number of houses in each category.[6] This test did not confirm, however, that the observed differences across the prices ranges were statistically significant.[7]

Table 5-4
Compliance Rates by Purchase Price

	$84,500 to $200,000	$201,000 to $400,000	$401,000 to $933,000
Percent Meeting Code	49.4%	45.9%	39.5%
Standard Error	9.0%	6.7%	7.8%

Heating Fuel and Heating System Type

Recent advances in the efficiency of gas furnaces and reduced prices of higher efficiency gas furnaces suggested that builders might be likely to opt for a higher efficiency gas furnace over building envelope improvements as a way to meet the code. MAS*check* explicitly accommodates tradeoffs between heating equipment efficiency and building envelope UA. To explore this hypothesis, we segmented the results according to fuel and heating equipment type.

The variation in compliance rate by fuel type is shown in Table 5-5. These data suggested that houses heated with natural gas or propane were considerably more likely to comply than those heated with oil. When we tested for the statistical significance of the differences, the results indicated that the variation was statistically significant at the 0.05 level, thus providing support that the observed differences were valid for the population of houses built to the code.

[6] This type of test was applied in most cases when we examined the significance of differences in the compliance rates by different segments.

[7] One factor that may contribute is that the ratio of window area to gross wall area is larger in more expensive houses; it ranges from 13% to 16% for the least expensive and most expensive groups of houses, respectively.

Table 5-5
Compliance Rates by Fuel Type

	Oil	Natural Gas	Propane
Percent Meeting Code	36.2%	54.9%	53.2%
Standard Error	6.2%	5.5%	21.8%

We also examined differences in the compliance level by heating system type. Table 5-6 shows the percent of houses complying for three different heating systems—forced-air furnace, boiler, and hydro-air.[8] These results suggested that a considerable difference existed across the heating system types, with houses that had furnaces almost twice as likely to comply as houses with boilers. The least likely to comply were houses with hydro-air systems, but they comprised only an estimated 7% of the population.

The significance test showed that the differences were, in fact, statistically significant. In this case, they were significant at less than the 0.01 level, providing strong statistical support for a difference in compliance rates across heating system types.

Table 5-6
Compliance Rates by Heating System Type

	Furnace	Boiler	Hydro-Air
Percent Meeting Code	64.0%	33.5%	27.3%
Standard Error	5.9%	4.7%	10.9%

Building Official Activity Level

Another factor that could be hypothesized to be related to the compliance rate was the level of activity of building code officials. Specifically, one might expect that in areas where the number of building officials was relatively small compared to the number of building permits that code officials would not be able to do as thorough a job enforcing the energy code; consequently, the compliance rate in these areas would be expected to be lower than in other areas.

Table 5-7 shows how the compliance rate varied across different jurisdictions by the number of building permits issued per code official. Our hypothesis suggested that where the ratio of permits to code officials was high, the compliance rate would be lower. The data showed a relationship consistent with this expectation. However, when we tested for the statistical significance, we found that the results did not vary at a statistically significant level across the categories. Consequently, we could not conclude that there was a significant effect of the building official's activity level on the compliance level.

[8] Hydro-air systems use a fuel burning boiler or hot water heater to produce hot water. The hot water is piped to an air handler, sometimes called a fan coil. Inside the air handler is a multi-row coil, through which the hot water is circulated. Air is then passed over the coil and distributed to the house via the ducts

Table 5-7
Compliance Rates by Building Official Activity Level

	# Permits/Building Official		
	5 to 21	29 to 64	91 to 171
Percent Meeting Code	51.1%	43.9%	43.2%
Standard Error	4.3%	5.9%	10.7%

5.1.3 Compliance Discussion and Reasons for Noncompliance

This subsection provides information about the enforcement and compliance process to highlight issues that were likely to affect the compliance level. It then presents quantitative results from the onsite data collection to help identify specific factors that appeared to be related to code compliance.

Enforcement and Compliance Process

In the course of collecting the current practices building data and conducting onsite surveys, we gained some insights into the code enforcement and compliance process. Because much of this information was anecdotal, we only summarize it briefly here. Section 6 presents a more extensive discussion of these issues based on a number of market actor interviews designed primarily to collect this type of information.

Most towns that we visited used some form of a pre-permit checklist that identified required file information including an item usually called the "Energy Report." Since permit applications were usually considered only after all these items were present, the Energy Report would have to be included in the file to proceed with the permit review.

Some towns did not allow builders to use the prescriptive packages to demonstrate compliance. Instead, they required the builders to use MAS*check*. One town had set up a computer terminal that builders could use to do their MAS*check* runs. Many of the builders had their insulation contractor (and probably other product suppliers) do their runs for them. One code official indicated that he helped about 10% of the builders he dealt with do their MAS*check* runs; he also expressed frustration at the lack of understanding on the part of builders.

Code officials who expressed reservations about the energy code and compliance process appeared to be the least likely to enforce the code sufficiently. In these cases, lower compliance levels determined through our MAS*check* analysis tended to be correlated with the code officials' level of concerns about the code.

Most officials indicated that they lacked the time in the field to do adequate code compliance inspections. Typically, they looked for the same types of energy-code compliance factors that they had enforced prior to the recent code change. There was little evidence that code officials understood the air sealing requirements of the new energy code or were enforcing them properly.

This information and other observations from the field data indicated that in some towns once the Energy Report (usually the MAS*check* output) had been filed it was probably never examined again. One preliminary conclusion that we drew from this was that the initial MAS*check* output was being used, at least in some jurisdictions, as an adequate demonstration of code compliance. In these cases, it appeared that noncompliance could have occurred during construction and not been caught because the MAS*check* results were not updated.

Noncompliance Issues

Since the code is performance-based and does not specify requirements by component, it is generally not possible to identify specific areas in which individual houses did not comply with the code. This is because the efficiencies of individual components or systems can be traded off against one another as long as the overall performance meets the requirement.

To gain insights into why houses did not comply, we looked at the construction data in several different ways. The onsite survey data provided useful information at an aggregate level about what might have contributed to noncompliance because the surveyors documented areas in which the pre-construction characteristics differed substantially from what was built. Another strategy we used was to identify differences in individual components between complying and noncomplying houses. Finally, we examined the relationship between heating system efficiency and code compliance.

Earlier, we presented overall information on the frequencies of a 10% difference between values reported on the compliance report and observed during the onsite surveys. Table 5-8 shows this information, but reported for houses that complied with the code and those that did not. The table shows what proportion of complying and noncomplying houses differed by more than 10% in the values for areas or perimeters, insulation levels, and window or door U-values. For areas/perimeters and insulation levels, there was no statistically significant difference. The U-values for glazing and doors, however, were considerably more likely to differ for noncomplying houses than for complying houses.[9] Over half the noncomplying houses had substantially different values, whereas only about one-third of the complying houses did. We did not do a detailed analysis of the differences, but the evidence did not suggest that the noncomplying houses had less efficient windows than planned.

[9] If labels were on the windows the U-value recorded was that on the label. In most cases, however, there was no label and the window was assigned the default U-value from the code.

Table 5-8
Percent of Houses with Significant Differences between Compliance Report and Actual Levels, Complying v. Noncomplying

Actuals Differ More than 10% from Compliance Report	Complying Houses	Noncomplying Houses	Statistically Significant Difference?
Areas/perimeters	76%	78.8%	No
Insulation levels	35.5%	29.9%	No
Glazing/door U-values	36.8%	50.5%	At 0.14 level

We compared the mean values of several building components for houses that complied with the values for houses that did not comply to determine if there were any significant differences. Table 5-9 shows that the wall and floor cavity mean R-values were larger for complying houses than for noncomplying houses, and the difference was statistically significant. The ceiling R-values, window and door U-values, and heated basement R-values did not differ significantly between complying and noncomplying houses. The other difference was that complying houses were more likely to have continuous insulation installed, but the share of complying houses with continuous insulation was still only between 5% and 10%.

Table 5-9
Comparison of Values for Complying and Noncomplying Houses

Component	Complying Houses n=84	Noncomplying Houses n=102	Statistically Significant Difference?
Ceiling cavity R-value, mean	31.2	31.8	No
Ceiling continuous insulation present	3 houses	0 houses	--
Wall cavity R-value, mean	14.9	13.5	<0.01 level
Wall continuous insulation present	7 houses	0 houses	--
Heated basement R-value, mean	13.0	12.5	No
Door U-value, mean	0.35	0.35	No
Window U-value, mean	0.461	0.468	No
Floor cavity U-value, mean	20.9	18.1	<0.05 level
Floor continuous insulation present	3 houses	0 houses	--
Slab	Insufficient sample		

These results suggested that, compared to complying houses, noncomplying houses were more likely to have less wall and floor cavity insulation installed and have no continuous insulation. For the walls, this meant that 2x6 framing, which would allow for insulation levels greater than about R-13 to be installed, was less common in noncomplying houses. In addition, the average stud spacing in noncomplying houses was 16.1”, compared to 16.4” in complying houses (statistically significant at the 0.11 level). Thus, 24” on-center (o.c.) spacing was less common in noncomplying houses, but 16” o.c. spacing was by far the most common for all houses.

Because the code permitted tradeoffs between the efficiency of the heating equipment and envelope components, it was also important to examine the relationship between equipment efficiencies and code compliance. The furnaces and boilers ranged in efficiency from 78% to 94.6% AFUE. All met the minimum requirement of the code.

As with the building components, we compared the efficiencies of heating equipment and how often the efficiency differed substantially between the compliance report and actual equipment installed in complying and noncomplying houses. Table 5-10 shows that the average efficiency was more than three percentage points higher in complying houses and that complying houses were twice as likely to have equipment with a different AFUE installed than what was shown on the compliance report.

Table 5-10
Average Heating Efficiency and Variation between Compliance Report and Actual Levels, Complying v. Noncomplying

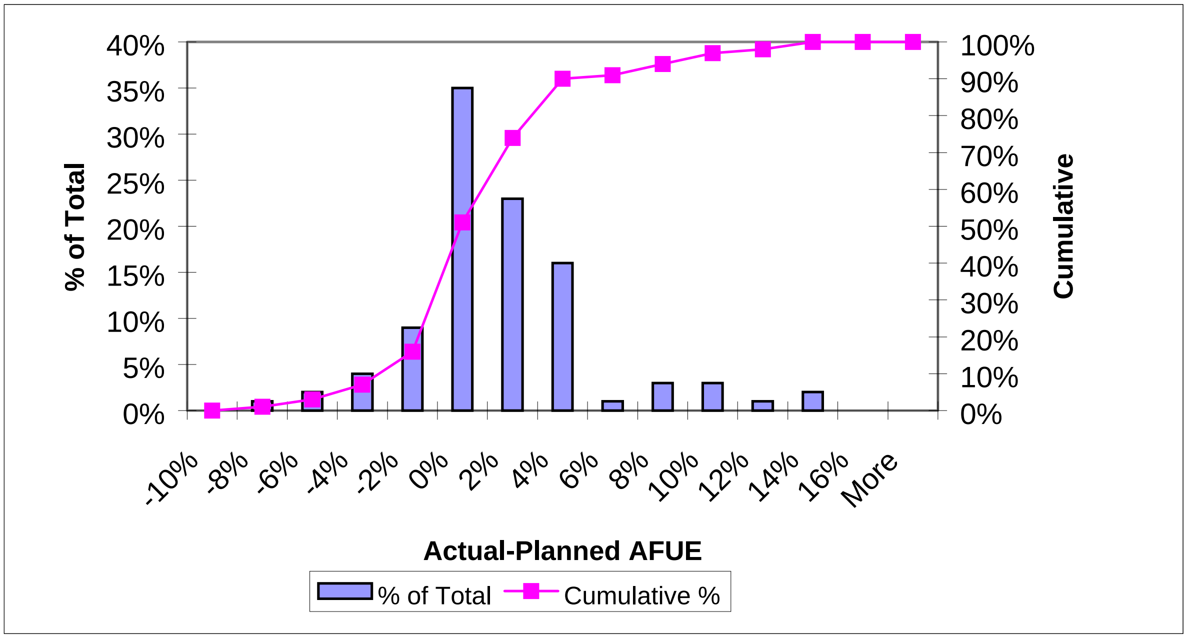
	Complying Houses	Noncomplying Houses	Statistically Significant?
Average AFUE	86.9%	83.5%	0.01
AFUE differs by more than 5%	32.1%	16.4%	Marginal (0.14 level)

To determine the effect of different efficiency levels on compliance, we had to examine the data in more detail. Installing less efficient equipment than planned based on the filed MAS*check* report could lead to noncompliance. On the other hand, installing more efficient equipment than planned could lead to a higher efficiency level than required by the code. To explore this issue, we compared the efficiency of the boilers and furnaces that were installed to the efficiency that was listed in the original MAS*check* report.

Figure 5-7 shows the distribution of the differences in efficiencies for the 100 homes for which we had the planned AFUE data.[10] The figure shows that 49% of the houses had more efficient equipment than originally planned; however, 16% of the homes had equipment with lower efficiencies than reported in the original compliance documents. About one-third had the same efficiency as initially reported.

[10] The results reported here were based on unweighted data.

Figure 5-7
Distribution of Actual Heating Equipment Efficiency Minus Planned Efficiency



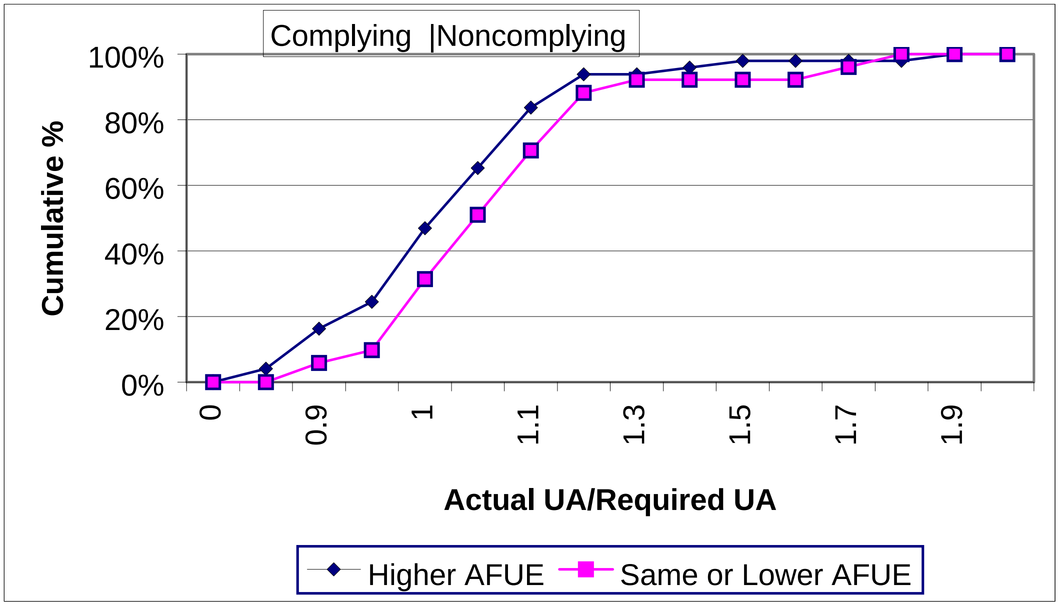
When we compared the compliance rates for houses with lower and higher efficiency levels than planned, the results showed that the compliance rate was substantially lower for houses in which less efficient equipment was installed than planned—only 20% of these homes complied with the code. On the other hand, for houses with more efficient equipment the compliance rate was slightly higher than for the sample as a whole.

The upper curve in Figure 5-8 shows the distribution of the ratio of the measured UA to the required UA for homes that installed more efficient heating equipment than originally planned. The lower curve is for homes with the same or lower AFUE than planned. The relationship of the curves shows that when more efficient equipment was installed homes were likely to perform better than required by the code. Twenty-four percent of the homes in which higher efficiency equipment was installed performed at least 5% better than required by the code, while only 10% of the remaining homes performed at least 5% better than required.

In summary,

- almost half of all the homes had more efficient furnaces or boilers installed than originally planned and
- those homes with more efficient heating equipment installed than planned were over twice as likely to be more efficient than required by the code.

Figure 5-8
Distribution of UAs for Equipment with Different AFUEs



5.2 ENERGY AND EMISSIONS IMPACTS

We estimated the energy savings impacts from the average house in terms of reduced consumption of electricity, oil, natural gas, and propane. We calculated the savings per house, per square foot of floor area, and by end use.

Table 5-11 shows the estimated average savings per house by energy type. Because there were essentially no energy savings for water heating, no estimates for water heating are reported in this table or in the following results. The table shows the estimated average magnitude of savings as well as the percent savings relative to the baseline (pre-code changes consumption levels). The average values over all houses takes into account all houses in the population whether they have the specific equipment or not.

Table 5-11
Annual Energy Savings per House

	Space Cooling	Space Heating			
	Electricity, kWh	Propane, Therms	Oil, Therms	Natural Gas, Therms	All Fossil Fuels, Therms
Complying Houses with Fuel/Equipment	196	370	245	331	302
Noncomplying Houses with Fuel/Equipment	136	139	228	244	231
All Houses with Fuel/Equipment	169	262	234	291	264
% Population with Fuel/Equipment	58.1%	4.3%	45.1%	49.9%	100%
Average over All Houses	97.9	11.3	106	145	264
Average % Savings Relative to Baseline	5.9%	27.4%	21.8%	24.5%	23.4%
Note: kWh is one kilowatt-hour. One therm is 100,000 Btus.					

Average energy savings per square foot of conditioned floor space are presented in Table 5-12 for those houses only with the specific equipment and fuel combination. Note that the units are different than those shown in Table 5-11 so that they are consistent with the usual units used to present energy use per square foot and have reasonable magnitudes.

Table 5-12
Annual Energy Savings per Square Foot of Floor Area for Houses with Fuel/Equipment

	Space Cooling	Space Heating			
	Electricity, Wh/ft^2	Propane, kBtu/ft^2	Oil, kBtu/ft^2	Natural Gas, kBtu/ft^2	All Fossil Fuels, kBtu/ft^2
Complying Houses	74.7	13.8	10.7	12.3	11.8
Noncomplying Houses	55.4	6.4	8.6	9.3	8.8
All Houses with Fuel/Equipment	67.0	10.4	9.3	10.9	10.2
Note: Wh is Watt-hours and kBtu is thousand Btus.					

In all cases, the average space heating and cooling energy used in both complying and noncomplying houses was less after the code changes than before. Houses that complied with the thermal performance requirements of the code saved about 50% more energy than those that didn't. About half the space heating savings were from higher insulation levels, more efficient windows, and higher efficiency heating equipment. The other half was from reduced air infiltration compared to houses built before the code changes. The changes in envelope thermal characteristics had less of an effect on air conditioning energy use and no air conditioner efficiency improvements resulted from the code changes. Consequently, the bulk of the air conditioning energy savings resulted from the infiltration reductions. The comparison between current and baseline infiltration rates is discussed later in this section.

We note that the estimated energy savings were based on a simulation model without calibration to actual energy consumption. Consequently, the estimated quantitative savings may over- or under-estimate actual savings. The percentage savings shown in Table 5-11 are probably a more accurate estimate of the relative effects of the code changes on energy consumption.

The energy savings estimates provided the data required to estimate emissions savings resulting from the code. To convert energy savings to an estimate of emissions reductions we multiplied the savings quantity for each energy source using the values reported in Table 4-1.

To estimate annual emissions reduction per house, we multiplied the population average energy savings values in Table 5-11 by the emissions factors to estimate the emissions reductions for the average new house. The results are shown in Table 5-13.

Table 5-13
Average Annual Emissions Savings

	SO_x	NO_x	CO_2
Average Savings per House	4.21 lb/yr	3.39 lb/yr	3,689 lb/yr
Total Savings for New Houses	30.4 ton/yr	24.5 ton/yr	26,600 ton/yr
Note: Estimate of new houses is based on U.S. Census data for housing units authorized (14,442) in 2000.			

5.3 CONSTRUCTION AND OPERATING CHARACTERISTICS

This subsection summarizes the characteristics of new houses in Massachusetts based on the 186 houses that we surveyed. The most significant characteristics are presented, extracted from the comprehensive database that we constructed. This subsection also presents information on typical temperature setpoints as reported by building occupants. More detailed information is presented in Appendix B and all the details are contained in the Excel database that we created to compile the data. The final subsection compares the mean values from our onsite surveys with the baseline values presented earlier.

The data presented here are based primarily on the MAS*check* inputs that we documented and used in our compliance analysis. Because each building could consist of multiple wall, floor, and ceiling sections whose characteristics could vary, it was too complex to determine a single weighted value that represented each building component. Generally, we used the weighted average values for the different sections of each building to estimate the overall characteristics of the envelope components.

5.3.1 Basic Characteristics

During the onsite surveys, we fully documented the dimensions and layout of each house. The data collected included conditioned space floor area, conditioned volume, number of floors, and foundation type. Table 5-14 summarizes these statistics.

Table 5-14
Summary Population Construction Characteristics

Characteristic	Mean Value	Standard Error of Mean
Conditioned floor area, ft^2	2,538	110
Conditioned volume, ft^3	20,945	986
Number of bedrooms	3.50	0.084
Number of floors on or above grade		
1	12.7%	2.7%
2	83.3%	2.9%
3	3.1%	1.9%
4	0.5%	0.5%
Foundation type		
Slab on grade	2.0%	1.3%
Vented crawlspace	0.0%	0.0%
Unvented crawlspace	0.0%	0.0%
Conditioned basement	7.0%	1.9%
Unconditioned. basement	86.2%	2.6%
More than one	4.7%	1.7%

The average house size was about 2,500 ft^2 and the conditioned volume was about 21,000 ft^3. The average house had between three and four bedrooms. Most houses had two-stories and the most common foundation type was an unconditioned basement. No houses had crawlspaces.

5.3.2 Envelope Insulation Levels and Framing Characteristics

Table 5-15 shows the estimated average ceiling, wall, and floor insulation levels based on all houses in our sample. For insulation types and locations not present in all houses, the values shown are for the houses with that insulation type, and the percentage of houses with that insulation type is shown.[11]

Table 5-15 presents the average insulation levels for houses that had the insulation type shown. It also shows what percent of houses had each type of insulation. Typically, two to three percent of the houses had continuous insulation in the different envelope components.

Table 5-15
Average Population Insulation Values for Houses with Insulation Type

Component	Mean Insulation R-value	Standard Error of Mean	% of Homes with Insulation Type
Ceiling cavity	31.5	0.34	100%
Ceiling continuous	3.75	0.84	2.00%
Wall cavity	14.1	0.28	100%
Wall continuous	2.70	0.22	3.46%
Floor cavity	18.6	0.60	98.4%
Floor continuous	3.29	0.97	2.03%
Basement	12.8	0.18	4.55%

5.3.3 Glazing and Door Characteristics

Table 5-16 summarizes the window characteristics. The mean U-values and window areas were calculated from data on all windows in each house. The average U-value was 0.41. Over half the windows had vinyl frames and about 40% had wood frames. The overall average ratio of window area to floor area was about 14%. Based on the entire sample and all wall components, we estimated that the average ratio of window area to gross wall area was 14.5%, but the value was not calculated for individual houses. The predominant window type was double-pane glazing without a gas fill. U-value information for the windows was available in only 4% of the cases; in the remainder the default value for the window type was assumed.

[11] In cases where data were available for more than one segment of a certain type, e.g., wall insulation, the values shown in the table were based on the first segment value entered in the MAS*check* inputs. Consequently the numbers reported in the table did not represent the overall weighted average values for the entire house. However, the values were generally very close when multiple segments were present so this did not introduce any significant error in the estimates.

Table 5-16
Window Characteristics

Characteristic	Value
Mean U-value	0.410
Mean window area	353 ft^2
Mean window area ratios	
to floor area	13.9%*
to gross wall area	14.5%*
Frame type	
Wood	41.6%
Vinyl	58.4%
Glazing type	
Single	0.6%
Single with storm	1.6%
Double	13.2%
Double with low-E	76.4%
Double with low-E with argon	8.2%

**The ratio of window to floor and gross wall area was calculated by adding up the gross areas of each wall component.*

Table 5-17 summarizes the mean characteristics of skylights. About one-third of the houses had at least one skylight. The average U-value was about twice the value for windows, primarily due to the use of metal frames and metal frames with a thermal break and a lower incidence of double-pane glazing with a gas fill or low-E coating.

Table 5-17
Skylight Characteristics

Characteristic	Value
Mean U-value	0.907
Mean total skylight area	18.1 ft^2
Frame type	
Metal	7.5%
Metal with break	30.9%
Wood	61.6%
Glazing type	
Double	72.7%
Double with low-E	24.2%
Double with low-E with argon	1.6%
Note: 58 (31%) of the 186 houses surveyed had one or more skylights.	

5.3.4 Air Conditioning Equipment

Table 5-18 summarizes information about air conditioners in new Massachusetts houses. Nearly 60% were equipped with central air conditioners and about half of these had more than one unit. The total cooling capacity installed averaged about 4.5 tons or 604 ft^2 of floor area per ton of capacity. Half the central air conditioners were installed in houses with ducted heated systems and the other half were installed with boiler systems. A little over 10% of the houses had one or more room air conditioners.

Table 5-18
Air Conditioner Characteristics

Characteristic	Value
Houses with central air conditioner	58.1%
Houses with more than one central air conditioner	26.9%
Mean total capacity of central air conditioner(s) in houses with systems	57,311 Btu/hr
Mean efficiency of central air conditioners, SEER	10.2
Houses with room air conditioners	11.3%

5.3.5 Heating System Type and Fuel

As shown in Table 5-19, almost one-third of the houses had a natural gas furnace and another third had an oil boiler heating system. Most of the remaining houses had either a natural gas boiler or oil furnace system. About 7% of the houses had a hydro-air system using natural gas, oil, or propane. About 16% had more than one central heating unit. The average total central heating system capacity averaged a little over 100,000 Btu/hr and the average efficiency for all the systems was about 86% AFUE.

Table 5-19
Heating System Characteristics

Characteristic	Value
Central system fuel and type	
Natural gas furnace	31.2%
Natural gas boiler	16.1%
Natural gas hydro-air	2.2%
Oil furnace	10.2%
Oil boiler	31.7%
Oil hydro-air	4.3%
Propane furnace	2.7%
Propane boiler	0.5%
Propane hydro-air	0.5%
Houses with more than one central heating system	15.6%
Mean capacity of central heating system(s)	100,780 Btu/hr
Mean efficiency, AFUE	85.6%
Supplemental heat used	
Space heaters	4.3%
Wood	2.2%

Supplemental heating systems were uncommon, with either space heaters or wood used in about 6% of the houses. Overall, the heat supplied by the central systems was estimated to be over 99% on the average.

5.3.6 Air Infiltration Rates

Air infiltration rates were calculated based on blower door tests on each of the houses surveyed. Table 5-20 presents the results.

Table 5-20
Infiltration Rates

Infiltration Rate	Mean Value	Standard Error of Mean	Minimum	Maximum
Natural, air changes/hr	0.342	0.0091	0.1	1.09
Measured, CFM_{50}	2464.0	94.50	750	7105

The mean natural infiltration rate was 0.342 air changes/hr (ACH). The minimum estimated rate was 0.1 ACH and the maximum was 1.09 ACH.

5.3.7 Duct Leakage

We conducted tests as described in Section 3 to measure duct flows and leakage in a small subset of the houses surveyed. In 22 houses, Duct Blaster tests were used in combination with a blower door to estimate duct flow and duct leakage to space outside the building envelope. The results are summarized in Table 5-21.

Table 5-21
Duct Flow and Leakage

Duct Measure	Mean Value	Standard Error of Mean	Minimum	Maximum
Total System Flow – CFM25	849.5	25.77	585	1147
Leakage to the outside - CFM25	182.9	7.09	124	288
Percent leakage to outside	21.6%	0.76%	14.4%	28.9%

The overall average duct leakage was estimated to be about 22% of the total flow. This was a relatively large value, suggesting that improvements to the duct sealing should be implemented.

5.3.8 Temperature Setpoints

The occupants of each house surveyed were asked what setpoints they used for both heating and cooling at different times of day. Table 5-22 shows the means for four different time intervals.

Table 5-22
Mean Reported Temperature Setpoints, °F

	6 am-8 am	8 am-5 pm	5 pm-11 pm	11 pm-6 am
Heating setpoint	67.8	67.3	68.3	66.0
Cooling setpoint	71.8	72.0	72.7	73.0

The results showed little evidence of heating setbacks and cooling setups. Some respondents reported that they set their heating temperatures back during daytime (8 am to 5 pm) hours when no one was home or during the night (11 pm to 6 am).

5.3.9 Comparison of Current and Baseline Values

Table 5-23 presents a comparison of several of the key energy-efficiency characteristics of houses built under the current code to baseline houses. The values shown for current practice are the estimated means for the population based on our sample of houses. In all cases except air conditioner efficiency, the current average values are more energy-efficient than the baseline values. The difference for air conditioners is probably due to sampling error and not a decline in air conditioner efficiency—essentially the data showed that air conditioner efficiency has not changed as a result of the code changes.

Table 5-23
Comparison of Key Current and Baseline Characteristics

Characteristic	Mean of Current Values	Baseline Value
Ceiling cavity insulation (attic)	R-31.5	R-30.9
Wall cavity insulation	R-14.1	R-13.6
Floor cavity insulation	R-18.6	R-17.6
Window U-value	U-0.41	U-0.495
Central air conditioner efficiency	10.2 SEER	10.3 SEER
Fossil fuel heating efficiency	85.6% AFUE	83.0% AFUE
Natural air infiltration rate, ACH	0.342	0.535

The envelope component efficiencies, in terms of R-values, have all increased slightly on the average. The biggest increase has been in floor cavity insulation levels.

The largest improvements have been in window and heating equipment efficiencies and a reduction in natural air infiltration rates. The average window U-value has improved by about 17%. Average heating equipment efficiency has increased by about 3%.

The largest improvement has been in the infiltration rate. Average infiltration has declined by 36%. The infiltration rates did not vary significantly between complying and noncomplying houses so significant energy savings occurred in both groups of houses.

The reasons for the substantial improvement in infiltration rates over the levels prior to these code revisions were not completely clear, but they were probably due in large part to the code changes and steps taken to implement the code. The revised code emphasizes the need for properly sealing joints, seams, or penetrations with durable caulking materials, gasketing systems, or permeable house wraps. Windows and doors also were required to meet specific air infiltration requirements, and the requirement for NFRC-certified windows probably led to overall reductions in the air leakage of installed windows. The major prescriptive changes were in requirements for recessed lighting fixtures. These prescriptive requirements alone, however, were probably not enough to account for the infiltration improvements.

One of the areas emphasized in the training conducted by the BBRS was the implementation of improved and consistent practices to reduce air leakage, and a substantial number of builders and code officials attended the trainings. The results from the market actor interviews, summarized in Section 6, indicated that the market actors rated this training as very effective at increasing awareness and knowledge. It was likely that this training increased builder and code official awareness and knowledge enough that both infiltration control practices and quality control improved during the construction process and these improvements were encouraged by improved enforcement practices.

Although the training and code changes probably accounted for much of the improvement, there was at least anecdotal evidence that in the past 5 to 10 years, there has been a trend throughout the country toward reduced infiltration in houses. Unfortunately, there was little documentation available to determine how much of the improvement observed in Massachusetts houses was attributable to a general trend, improved practices required by the code, or the training. However, the improvement was substantial and statistically significant and we have included the benefits of the infiltration reduction in our analysis. In the case of space heating, about half the energy savings were attributable to reduced infiltration.

6 MARKET ACTOR EXPERIENCES

We conducted interviews with five key groups of housing market actors to provide qualitative assessments about the implementation of the 1998 amendments to the code.[1] These qualitative data, obtained primarily from in-person, open-ended interviews were intended to provide an understanding of the following issues:

- how the code changes were perceived by people who must work with them daily;
- how well the higher energy-efficiency standards and increased emphasis on energy efficiency were being integrated within the residential new construction market; and
- what actions might be taken by the BBRS to enhance the energy code's effectiveness.

The research approach we used to address these issues is discussed briefly, followed by the interview findings. We operationalized collecting information on the general research issues above through research questions, developed in conjunction with the BBRS, that provided the basis for interview protocols for each market player group (see Appendix D). After the overview of the research approach, this section presents the interview findings, organized by these research questions.

6.1 OVERVIEW OF APPROACH

The BBRS identified five types of market players whose attitudes, understanding, and actions concerning energy code implementation were to be researched. These players included the following:

- local and state building code officials
- designers
- developers (build approximately 25 houses or more per year in Massachusetts)
- builders (build approximately 2-20 houses per year in Massachusetts)
- suppliers.

Local building code officials are responsible for all building code enforcement activities within the state. To help achieve its goals, the BBRS offered training to all local officials in the state through a series of workshops prior to the implementation of the new code. Of 750 local code officials in the state, 621 participated in training. The Massachusetts Department of Public Safety employs 14 state building officials in six regions. Their primary function is to serve as state building code officials of record for state-owned buildings, but they also provide training to local code officials on a variety of building code related issues.

[1] See Appendix D for a more detailed discussion of the material in this section.

Designers have the key role of developing house designs that conform to the energy code requirements, and providing detailed specifications for local officials to review and homebuilders to translate into materials purchases.

For this study, we defined "builders" as companies that build from 2 to 25 houses per year in Massachusetts; this group builds about 70 per cent of new houses in the state. "Spec" builders generally build a small number of houses at a time from standard plans or plans they have developed on their own, and sell the houses with minimal buyer choice in modifications or options. "Custom" builders are more likely to be involved in home design and work with the buyer from an early stage. Custom houses tend to be larger, more expensive, and have more options than spec houses.

For this study, we defined developers as builders of more than approximately 25 new houses per year. Developers offer a wider range of features to prospective customers.

Suppliers we interviewed primarily included general building materials suppliers encompassing local and regional companies as well as at least one national chain. We also interviewed two suppliers who specialized in building insulation. Suppliers provide the materials for new home construction and also provide advice to builders about specific materials and equipment. Some suppliers also do entire house designs for their builder customers. A number of suppliers also provide the service of completing the MAS*check* analysis for their customers.

We had a goal of completing approximately 50 market actor interviews. Table 6-1 shows how the interviews were allocated across the different groups. We conducted in-depth interviews with a total of 52 individual market actors, but counted the group of state inspectors as a single interview.[2]

Table 6-1
Interview Allocations and Completions

Market Actor	Interview Goal	Number Completed
Builder	12	12
Developer	9	8
Designer	8	9
Supplier	8	9
Local Code Official	11	11
State Code Official	1 (group of 3 or 4)	1 (group of 3)
Total Interviews	**50**	**50**

[2] This group was not part of the original proposal; we suggested including it to gain perspective on regions of the state that might have been otherwise excluded.

The sample selection procedure is discussed in Section 3, which provides summary information on the characteristics of single-family houses being designed and built or inspected by market players interviewed for this study.

After the interviews were completed, we compiled the information gathered around the research questions posed at the beginning of the process. The intent was to provide qualitative data about the environment in which the code was being implemented and the enforcement and compliance processes. The results provided insights into these fundamental issues and identified opportunities for improving code implementation. Because the sample sizes were relatively small and the emphasis was on qualitative issues, we made no attempt to estimate quantitative results for the populations of the different market players interviewed.

6.2 FINDINGS

The findings are summarized here organized around eight groups of research questions. The findings are presented following each group of numbered research questions.

1. How knowledgeable are the different groups about energy efficiency? How have the different groups learned about the energy code? What role has training, especially the training sponsored by the BBRS, had in increasing understanding and awareness of the code among the different market actor groups?

We asked each market player to use a scale (excellent, very good, good, fair, and poor) to assess the knowledge level about general energy-efficiency issues among their peers and other market players. Table 6-2 summarizes how each market player group rated the knowledge of all groups.

Table 6-2
Assessments of Market Players' Energy-Efficiency Knowledge

Rated / Rater	Designer	Developer	Builder	Supplier	Local Code Officials
Designer	Good to Excellent	Fair	Poor to Fair	Fair to Good	Fair to Good
Developer	Good to Excellent	Good	Poor to Fair	Good	Good to Excellent
Builder	Good	Good	Good to Very Good	Good to Excellent	Fair to Good
Supplier	Excellent	Good	Poor to Fair	Very Good	Good to Very Good
Local Code Officials	Good to Very Good	Fair to Good	Poor to Fair	Good	Good to Very Good

Most respondents rated their own knowledge levels to be very high, and generally higher than most of the other market players. Most groups rated builders as the least knowledgeable group. Designers received the highest ratings. Most market players rated local building code officials' knowledge as good. Respondents from all groups often expressed a desire for more information on energy efficiency, including recent advances and better practices, and most looked to the BBRS and their own professional associations as good sources of information.

Based on the interviews, we made the following observations:

- There was great variability in both the level of energy-efficiency knowledge and interest among all groups.
- Designers and suppliers appeared to be most conversant with energy-efficiency principles and practices.
- Among developers, levels of knowledge and interest were highest among project managers and others with direct responsibilities for management and oversight of construction.
- The smallest builders tended to be the least concerned and least knowledgeable about energy efficiency—most have pursued their craft for many years and have "tried and true" ways of doing things. This group also tended to prefer prescriptive approaches over flexible ones such as MAS*check*.

All market players reported that they were well acquainted with the changes to the residential building code. The information channels through which market actors learned about the code changes varied somewhat by group as summarized in Table 6-3.

Table 6-3
Code Information Channels

Market Actors	Code Information Channels
Local building code officials	• Principally BBRS workshops (10 of 11 interviewees) • State building code official training sessions • Regional building code officials association meetings
Design professionals	• Principally professional publications • Other designers (in larger firms) • Professional organizations • Local building code officials
Builders	• BBRS workshops • Local building code officials • Other builders • Regional chapters of the homebuilders' association • Suppliers (especially for less sophisticated builders)
Developers	• Trade publications • Designers • Local code officials (to a limited extent)
Suppliers	• BBRS training • Product and material vendors

Thirty-one of the 52 market players interviewed had participated in some formal training prior to the implementation of the code as shown in Table 6-4.

Table 6-4
Number of Interviewees Who Attended Formal Training

Market Player	Number in Category Interviewed	Number Trained
Developers	8	1
Builders	12	6
Designers	9	4
Suppliers	9	7
Local Building Code Officials	11	10
State Building Code Officials	3	3
Total	**52**	**31**

As noted earlier, the BBRS put on a series of workshops, before code implementation, to inform the industry about the code changes, including the use of prescriptive packages and the MAS*check* computer program, which is a basic part of compliance with the new code requirements. Table 6-5 summarizes information about the sessions. Building materials suppliers and regional builder and building official associations sponsored many of the sessions.

Table 6-5
BBRS Training*

Session Type	Number of Sessions	Participants
Contracted all day sessions targeted to builders, architects, others**	3	69
Contracted 3-hour sessions**	28	811
BBRS staff sessions sponsored by suppliers, builder associations, etc.	60	3,967
BBRS staff 1-hour sessions on MAS*check*	16	405
BBRS brief outreach presentations at community events	30	2,209
Totals	***137***	***7,461***
*Source: BBRS **Sessions provided by outside agent with funding from the U.S. Department of Energy		

Observations by the local building code officials' about the BBRS-sponsored training included the following:

- Most recalled the training as effective and informative.
- Opinions differed on whether the training should have a more theoretical or more practical emphasis.
- Some believed a more checklist-oriented approach would be more relevant.

- Several requested that BBRS initiate refresher training for experienced staff, as well as provide another round of basic training for new local building code officials.

Other participants provided the following observations:

- Overall, most felt the training was useful and should be periodically updated.
- Only a few who were interviewed several months after training could recall many details, however.
- Many recalled demonstrations of the MAS*check* software.
- Builders were concerned about training taking away time from on-going work.

Recommendations from the interviewees about the training and information dissemination included these:

- Hold the training during the slow building season (if there is one).
- Provide the opportunity to purchase the state building code, including recent and anticipated code changes, on a searchable CD-ROM when builders renew their licenses.

2. How, and to what extent, are local code officials monitoring and enforcing the energy code requirements? Are there aspects of the code that are enforced to greater or lesser degrees? To what extent does monitoring and enforcement vary among localities? How educated about the code are local officials? Do local code officials use MAScheck interactively with designers and builders? Do they find value in using MAScheck as a tool for documentation and enforcement? Is there a need for additional training or educational materials?

Local building code officials were clearly enforcing the energy code among the communities we contacted, but they did so as public officials whose highest priorities were the public safety aspects of the code. They expressed concern about structural integrity of new houses, safe installations of electrical and combustion appliances, environmental issues such as design and installation of sewage, and similar safety concerns. Some officials expressed concerns about energy-related aspects of houses, such as adequate air for combustion appliances, moisture transport around insulated spaces, and, in a very few cases, proper ventilation and indoor air quality in living spaces.

Though most local building code officials expressed support for the energy code changes, they gave enforcement of those sections of the residential building code lower priority than safety-related issues throughout the application and inspection processes. In the towns we visited, submission of a MAS*check* printout showing a passing score was a required part of the application process for a new home construction permit, but in most towns that was about the end of the process. Comparing MAS*check* inputs and building plan specifications for net window and wall areas was uncommon. Checking the MAS*check* run against new houses as they were being constructed was very rare. MAS*check* has an important role as a primary piece of documentation, but the lack of follow-up in many communities could encourage permit applicants to “adjust” specifications on plans that might otherwise fail.

Enforcement of insulation and sealing requirements through onsite inspections was uneven. Some communities had specific insulation inspections, but many inspected insulation and sealing as best they could, and might not view some insulated areas that have been enclosed. Responsibility for insulation and sealing of ducts and penetrations was not consistently assigned among towns and some inspection opportunities might be missed because of that.

Local building code officials did not use MAS*check* as a design tool or work interactively very often with builders or designers in new construction. Homeowners doing additions and renovations as their own general contractors appeared to get a great deal more attention, however, because local building code officials believed they needed the extra help to produce compliant designs.

Code officials appeared to be knowledgeable about the code, but more than 18 months after its implementation, a number of them expressed interest in refresher training for experienced staff and introductory training for new staff who were not exposed to the initial training round. Specific requests were made for checklist approaches to focus on energy issues and organize the inspection process to capture all the significant energy aspects.

3. How do designers and large and small builders view the energy code? Are they aware of the major provisions? Do they see the different code compliance approaches as a benefit in providing them with greater design flexibility? Do they regard compliance as a barrier to completing their projects on time and on budget? Do they find enforcement to be similar across jurisdictions? Does the pattern of enforcement affect decisions to pursue projects in specific localities? What could the BBRS or other parties do to assist in better use of the current code's compliance tools?

Designers, developers, and most builders were aware of the energy code provisions. In general, members of all of these groups favored the energy code provisions, and did not see the code as a significant barrier to designing and building houses their customers could afford. Designers noted the code added time (and therefore cost) to change basic specifications to meet the code. They also noted that running MAS*check* imposed a time and/or a convenience penalty on most of them because most designers use MacIntosh™ computers and MAS*check* is available only in the Windows™ operating system format.

Spec builders were more likely to see the code as imposing additional time and costs that affected the ways they have traditionally built houses. At least one small builder believed the code served to make houses less affordable to his potential customers, but this was a distinctly minority point of view.

Everyone in all market player categories agreed that enforcement varied among communities. Local building code officials indicated reasons for variations included their overriding public safety priority; variability in interest in certain energy efficiency aspects of construction, differences in knowledge levels; special local concerns; inadequate staff and time, and similar concerns. Designers and builders generally found that, though towns differed in the degree of enforcement and its emphasis, most towns had a consistent approach to the energy code; the designers and builders adjusted accordingly from community to community. Designers and builders also said they did not find variations in energy code enforcement to be much different from variations among towns in the enforcement of other aspects of the building code. During the course of these interviews we found no indications that the patterns of energy code enforcement affected developer or builder decisions to build in any particular town. As noted elsewhere, small builders and some smaller developers tended to concentrate their operations within a few towns or a region. This concentration provided them with repeat exposure to the same local building code officials, providing some certainty of how the code would be enforced in any given community.

The local building code officials indicated that it would be helpful if the BBRS provided them with—

- checklist approaches to energy code enforcement;
- refresher training and training in new materials and installation techniques;
- a consensus of critically important energy issues to be spotlighted in inspections.

4. What designer, builder, and supplier practices have altered since the implementation of the code? Are these changes improvements? If they have experience in other states that have adopted CABO MEC 95, how do they compare that with implementation in Massachusetts? What would they change?

Aside from the use of NFRC-certified windows (discussed later), there did not appear to be a great many changes in building practices that were directly attributable to the energy code implementation. There was increased use of 2x6 framing in some areas to accommodate more wall insulation, primarily in the colder central and western parts of the state. In southeastern Massachusetts, however, which is both the warmest part of the state and the region with the highest levels of building activity, there was mixed adoption of this measure, because climatic conditions did not always require more insulation (and the accompanying framing).

Some designers have increased their use of rigid insulation, especially in cathedral ceilings. There was some reported increase in under-floor radiant heating systems. There was some indication that installing heating systems above the efficiencies specified by the energy code had become fairly common, but this appeared to be more of a market phenomenon, and the extent of this activity could not be verified. Some players also reported increased use of multiple heating systems in larger houses to decrease duct runs and increase resident comfort.

The code requires heating system sizing to be governed by the requirements of the Air Conditioning Contractors Association's Manual "J" (or equivalent procedure)[3]; this requirement should lead to the installation of lower capacity equipment in homes that have lower heating loads as a result of making the building tighter and more energy efficient. We found very little

[3] 780 CMR Appendix J, based upon the Council of American Building Officials Model Energy Code 1995 Edition

indication, however, that sizing practices have changed with the implementation of the revised code.

Heating and plumbing contractors are key to this process. Most designers, developers, and builders said they relied on plumbing contractors, assumed those contractors abided by the code requirements, and did not know themselves what actual sizing practice was (and had not inquired about it). Additionally, several builders said they preferred to oversize units, by values ranging from 25% to 50% above the requirements calculated for their buildings.[4] Reasons stated for this practice included these:

- Buyers are less likely to complain that the unit could not provide enough heat in cold weather.
- Homeowners are likely to build onto their homes, and larger units will be able to meet the future increased loads.
- Oversized units don't work as hard and are likely to last longer than those sized just right.

Builders who routinely oversized said that the impact of using larger heating systems on housing cost was too small to matter. They also said that homebuyers rarely inquired about efficiency and never inquired about sizing.

Suppliers of general building materials and insulation have provided important support to their builder customers, particularly those suppliers who run MAS*check* for builders. Suppliers often recommend the types and quantities of materials that builders should purchase. General building materials suppliers in most areas of the state were supportive of increased 2x6 framing, but they did not appear to identify or lead their customers to other significant changes in materials. Insulation suppliers were heavily involved in the use of fiberglass batts in most applications, which appeared to be their traditional business product. Aside from advising builders on the latest techniques for full coverage and proper sealing, insulation suppliers noted mainly increases in the R-value of batts and increased use of extensions to ensure that cavities were sufficient to install larger, thicker batts.

We asked market players about the effects of the code on housing costs. Most respondents found this a difficult question to answer but, on reflection, placed the additional costs in the range of $1,000-$3,000 per house, with the greatest increases coming from upgraded windows, insulation, and framing. Considering that the typical house being built by most builders was priced between $250,000-$350,000, this seems like a modest increase, but the estimate should be regarded as very inexact.

Designers, developers, and builders who had experience outside Massachusetts did not comment much on comparative implementation of the codes. Designers who had some familiarity with the IEEE2000 standard noted that that standard deals with ventilation in ways not addressed in CABO MEC 95, and were generally in favor of the updated approaches to handling ventilation in living areas.

[4] Note that the code permits oversizing up to 25% above the design load requirements.

5. How have all parties adapted to requirements concerning use of NFRC-certified windows? Are the MAScheck provisions for custom windows adequate? Do prescriptive window paths meet a real need? Has the new code affected perceived designer or customer demand for more energy-efficient windows? Are window manufacturers and supply houses providing adequate choice of conforming NFRC-labeled products?

The adoption of NFRC-certified windows for new construction appeared to be very successful. Almost all parties had praise for this aspect of the code (with the exception of two spec builders). Some designer had concerns about unusual window designs, but, overall, designers had found they were able to work well within the code requirements. Importantly, several developers and builders noted that the window requirements had "leveled and raised the playing field." In the past, virtually any window could be called energy efficient. Consequently, builders who installed truly more efficient, more costly windows were at a competitive disadvantage against builders who used the cheapest product available but still claimed energy efficiency.

We found very little mention of or interest in prescriptive window paths among custom designers, and not at all among market players dealing in standard designs. Developers and builders uniformly named national brand companies as their window suppliers and none complained about any difficulties with the products they now used, except for some problems with getting certification labels to adhere early on in the changeover.

The window supply market appears to have responded well to the increased need for NFRC-certified windows. No supplier, developer, or builder cited any instances in which they were unable to obtain the particular products they needed in necessary quantities. Time to fill orders seemed to have increased early in the implementation of the new code, but in the middle of a very busy building season there did not appear to be any current supply problems.

6. To what extent have building design, development, and construction players adopted MAScheck as a preferred or commonly used tool? What features of MAScheck are particularly useful or valuable? What barriers are there within the software package or its application that inhibit its wider use? What changes might be made to widen its adoption and/or increase its effectiveness?

MAS*check* is not a design tool in the sense that it is used to determine how houses should look, be laid out, or function. The designers, as well as developers and builders, we interviewed indicated that MAS*check* was used at the end of the process to ensure energy code compliance. Custom house designs sometimes required reconfiguration of large glass areas, such as window walls, after MAS*check* was run. No one we spoke with, however, used MAS*check* in a proactive manner.

Designers suggested two changes that might improve and extend MAS*check*'s use in the design process: 1) revise MAS*check* to be compatible with popular computer-aided design (CAD) file formats and 2) produce a version of MAS*check* compatible with the MacIntosh operating system, since most designers still use "Macs" for their design work.

Other market players also regarded MAS*check* much the same as designers. For those developers and builders who built essentially the same house over and over again, MAS*check* had minimum value. Spec builders who built only a few houses each year and had suppliers run MAS*check* for them might be missing an opportunity because suppliers reported that builders often did not tell them what efficiency heating system would be used; in the absence of that information, suppliers used the default efficiency values and perhaps overstated the amount of needed insulation, or understated allowable window areas.

7. How important are the existing prescriptive packages? Do they cover enough 'typical' construction situations to be broadly applicable? Are the different types of players (designers, builders, suppliers) satisfied with the prescriptive solutions? For those who have experience with MAScheck and prescriptive packages what are the strengths and weaknesses of each?

Prescriptive packages did not appear to be much of a factor in current new construction.[5] Prescriptive path solutions appeared to be more applicable to renovations and additions to existing structures in the current market. There are approximately 30 prescriptive packages in all. The number of packages to choose from can be filtered by applying climate, window area, and some other criteria, but in general market players appeared to be unaware of the packages or they ignored them.

Some players had a definite interest in a prescriptive approach to determining which energy-efficiency measures should apply to residential new construction. Those players who preferred a prescriptive approach believed it would be most valuable if applied broadly with a series of simple tables, e.g. in Climate Zone 1, "attics should always be insulated to R-38," and so on. These players believed the end results would equal those obtained with MAS*check*.

8. What could be done to foster proactive attitudes toward enforcement of the energy code and use of the software tools to increase greater energy efficiency in new residential construction?

There was a generally positive attitude toward the energy code on the part of almost all market players interviewed for this study. Almost everyone interviewed believed houses built under the energy code will be more efficient and comfortable for residents (barring some concerns about ventilation and indoor air quality).

Local building code officials, however, generally assigned energy code enforcement a low priority among their many responsibilities. MAS*check* submissions rarely received more than cursory reviews; as noted earlier, there was not much checking between MAS*check* printouts and

[5] This was consistent with the findings from our onsite surveys described in Section 5.

building plans submitted with applications; and there was very little onsite checking of the MAS*check* inputs on building sites.[6]

Increased and more thorough enforcement of the energy code requirements would be needed to increase overall compliance. However, energy code enforcement often was rated as a low priority among the many code responsibilities of many local building code officials.

The interviews suggested that the BBRS could take at least the following steps to improve the situation:

- Provide more training and tools to make the job easier to do in the limited time that local building code officials have available.
- Examine modifying the compliance rules to permit more use of broad prescriptive measures, in addition to the MAS*check* compliance path.
- Inform code officials about the importance of verifying the MAS*check* inputs in the field and reflecting changes in the building to ensure that the as-built building still complies with the code.

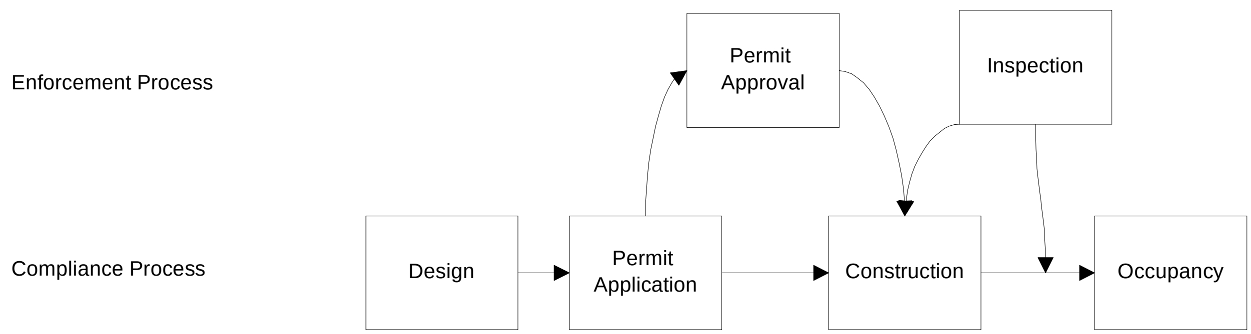
[6] Data reported in Section 5 were consistent with this finding—less than 50% of the houses reviewed complied with the thermal performance requirements of the energy code.

7 CONCLUSIONS AND RECOMMENDATIONS

The overall goal of this study was to assess the effects of the residential energy code revisions that went into effect in Massachusetts in 1998. This analysis, in turn, provided the basis for recommendations on the implementation process that should be instituted or investigated further as ways to improve the effectiveness of the code.

To provide context for our conclusions and recommendations, it is useful to identify the steps in the process through which an energy code affects the performance of a new building. Figure 7-1 portrays the key steps from building design through occupancy. The figure shows two paths—one is the compliance process through which the building industry achieves compliance with the code and the other is the enforcement process through which building officials ensure that the code is enforced.

Figure 7-1
The Building and Compliance Process



During the design process, the designer needs to prepare a design that complies with the code. The design information is incorporated in the permit application. The code official is responsible for ensuring that the proposed design meets the code requirements and construction can then proceed. During construction, the builder and subcontractors need to incorporate the features identified in the permit application that are required for compliance. To ensure this happens, code officials conduct inspections with a final inspection usually occurring after construction is completed. The buyer then takes possession of the house and occupies it.

The effects of the 1998 code revisions depended on the actions that occurred at each step in the process shown in Figure 7-1. Our study examined documentation that was filed at the beginning of this process and we performed post-construction surveys to determine the actual construction characteristics of the houses in our sample. We also conducted analyses of the energy usage and emissions associated with each house in our sample; these results were based on simulations of performance rather than actual performance data (such as energy billing data). The data we collected permitted us to assess the effectiveness or outcomes of each step in the process.

This first subsection summarizes the major conclusions drawn from our analysis. Based on these conclusions and feedback provided by market actors, we also present recommendations on how the process could be improved.

7.1 MAJOR CONCLUSIONS

The conclusions are presented in four areas—observations about the code and implementation process, compliance rates and factors related to compliance, causes of noncompliance, and code impacts.

7.1.1 Observations about the Code and Implementation Process

Based on feedback from market actors, the BBRS has done a good job of informing residential construction professionals about the features of the code regarding the design, permit application, and construction requirements for new residences. Market actors indicated that the requirements were well known and understood throughout the industry. Consequently, code awareness and understanding appeared to be quite good two years after the code changes had gone into effect.

Other market actors rated builders as the group least knowledgeable about the energy code. Smaller builders, in particular, were considered to be the least well informed. Designers and suppliers were rated as the most knowledgeable. Consequently, it appeared that the code requirements were most likely to be implemented properly during the design phase, but were most uncertain during construction.

All market actor groups indicated they could use more information on energy efficiency, particularly on new products and techniques. Most said that they looked to the BBRS and its trainings and to professional organizations and other professionals for information. Most respondents indicated that refresher training courses would be helpful.

The acceptance level of the revised code was generally quite high. Many market actors noted that the code requirements had increased the overall quality of houses being built, and particularly cited the NFRC certification requirement for windows as a significant upgrade.

The use of MAS*check* was the most common method to demonstrate compliance at the permit stage. Market actor feedback suggested that the BBRS had been successful in promoting the use of MAS*check* software to ensure compliance at this stage. MAS*check* was universally used by local building code officials and had become an integral part of the permitting process. Every community we surveyed indicated that MAS*check* printouts were expected to accompany all permit applications for new residences.

Market players accepted the need to use MAS*check*. Most players were supportive of MAS*check* and its flexibility, but relatively few market players appeared to make a great deal of use of that flexibility. Except for custom houses, most new houses being built used a limited pool of popular designs, with small, largely cosmetic variations to differentiate them to the buying public.

Several designers noted, however, that the Windows™ operating system format of MAS*check* was not compatible with their MacIntosh™ and CAD design systems.

Although MAS*check* was widely accepted, it often functioned as just another piece of documentation required to obtain a permit. Examination of MAS*check* submissions was spotty and almost always limited to a review of the printout for a passing score. Only a few communities crosschecked building specifications on the MAS*check* printout against the building plans or performed any site checking between MAS*check* and what was actually constructed. Local building code officials acknowledged these observations, and our onsite surveys confirmed that large discrepancies often existed between the data on the MAS*check* output filed with the permit application and the characteristics of the building as-built.

One conclusion suggested by these findings was a potential downside to the use of MAS*check*: some code officials may have begun to rely on the initial MAS*check* filing as an adequate verification of code compliance and not followed through adequately during construction and post-construction inspections.

Both building industry members and code officials suggested there was a need for a more checklist-oriented approach that could be used to highlight energy-efficiency requirements, especially as a means to organize the inspection process.

Market actor interviews indicated that onsite inspections of insulation, penetration sealing, and duct sealing requirements were generally insufficient, and varied considerably from area to area. Our onsite surveys confirmed these observations.

In our review of filings with building departments, we were unable to determine the code compliance approach used in nearly a third of the cases. This suggested that record keeping was not adequate in a significant minority of the cases.

Although there was interest by some builders in a more prescriptive approach to demonstrate compliance, we found that only 2% of the houses used the prescriptive package compliance approach.

Enforcement of the energy code appeared to vary significantly among communities, although most market players believed enforcement was consistent within a community. Interviewees noted that these discrepancies in enforcement were not greater than for other parts of the code.

Overall, referring back to Figure 7-1, these conclusions suggested that the effectiveness of the code implementation process varied. During the design process, it appeared to function well to lead to complying designs. During construction, however, it appeared to be less successful because construction varied from what was proposed in the initial design; the code knowledge of builders was limited; and building officials often did not compare the construction characteristics to the proposed design, rarely required an update of the MAS*check* analysis, and conducted only limited inspections of certain building components.

7.1.2 Compliance Rates and Factors Related to Compliance

Based on our thorough surveys of nearly 200 houses, only 46.4% complied with the overall U-value performance requirements of the code. However, 80% either complied or did not exceed the allowable U-value by more than 10%.

Overall, the as-built characteristics of the houses often differed substantially from the characteristics identified in the permit documents. Areas and perimeters were the most likely to differ—nearly 80% varied significantly. About one-third of the houses had insulation levels that differed substantially from the values in the permit documentation.

Our onsite surveys confirmed the market actors' observations about poor compliance with the penetration and duct system sealing requirements. More than 80% of the houses failed these requirements.[1] The effects of inadequate duct sealing showed up in our duct system test data, which indicated that duct losses to the outside averaged about 22%. Good duct sealing practices should be able to reduce average losses to 10% or less. Air infiltration data, however, showed that most houses were well sealed.

The sizing of heating systems also failed to meet the code requirements in a majority of the cases. The average system was oversized by 35% over what the code allowed. Only about 19% of the houses had heating systems that met the requirements. On the other hand, we found that cooling systems typically met the sizing requirements. We found that the sizing requirements of the code lacked clarity for combined water and space heating systems.

Houses heated with natural gas or propane were much more likely to comply with the code than those heated with oil. Only a little over a third of the houses with oil heat complied with the code. Houses with furnaces were twice as likely to meet the code than those with boilers—64% of the houses with furnaces met the code, whereas only 34% of those with boilers did. Both these results were related to the fairly common use of high efficiency (>90% AFUE) gas furnaces.

Compliance rates were considerably lower in the coldest areas of the state. Only about one-third of the new houses met the code requirements in areas with more than 6,400 HDD and, therefore, stricter code requirements.

[1] We took a strict "all or nothing" approach in assessing compliance with the sealing requirements.

Given the added requirements that this code placed on code officials, it seemed likely that compliance levels would be related to the workload of code officials. There was some evidence that the compliance rates were lower in the areas where code officials had to process more houses, but the differences were not statistically significant.

Although there was no code requirement for home occupants to set back thermostats to reduce heating energy consumption, this is clearly one strategy that reduces heating energy use. Our onsite surveys found that the self-reported thermostat setpoints showed that only a small proportion of occupants regularly set back their thermostats.

7.1.3 Causes of Noncompliance

Because this code was based primarily on a performance approach, it was not possible to pinpoint specific areas of noncompliance. However, by comparing the characteristics of complying and noncomplying houses we were able to identify the features that were more likely to be in complying houses. Using these comparisons, we drew the following conclusions about what contributed to noncompliance:

- Noncomplying houses had less insulation in wall cavities, on the average. This finding implied that complying houses were more likely to have 2x6 framing in the walls, thus allowing the installation of R-19 insulation. Another possibility would be the use of higher density batt insulation that provided a higher R-value in a 2x4-framed cavity.
- Noncomplying houses had less insulation in floor cavities. The average R-value in complying houses was about R-2 higher than in noncomplying houses. The differences could be attributable to deeper framing, the selection of higher R-values in the same cavity space, or the use of higher density batts.
- Noncomplying houses were very unlikely to have continuous insulation in the envelope components. Although only a small number of complying houses had any continuous insulation installed, none of the noncomplying houses in our sample used any continuous insulation.
- Noncomplying houses, on the average, had heating equipment that was about three percentage points less efficient than the equipment in complying houses.
- Poor duct sealing practices contributed to noncompliance. On the average, duct losses were estimated to be about twice the level that should be achievable with good sealing practices.

7.1.4 Impacts of the Code

The energy code provided direct energy savings for occupants and emissions reductions that benefited society at large. Table 7-1 summarizes the estimated annual energy savings for central air conditioning and all space heating types. Average air conditioning savings were about 6% and space heating savings were about 23% of the baseline levels. We note that these estimates were based on a simulation model and, since data were not available on actual consumption, the results may overstate or understate the actual impacts.

Table 7-1
Annual Energy Savings per House

	Space Cooling Electricity, kWh	Space Heating, All Fossil Fuels, Therms
Complying Houses with Equipment	196	302
Noncomplying Houses with Equipment	136	231
% Population with Fuel/Equipment	58.1%	100%
Population Average Savings	97.9	264
Average % Savings Relative to Baseline	5.9%	23.4%

The table shows that, on the average, energy savings occurred for both houses that complied and did not comply with the code. However, the space heating and cooling energy savings for complying houses were about 50% larger than they were for noncomplying houses.

Reduced use of fossil fuels for heating and electricity for cooling produced emissions reductions. Table 7-2 summarizes the annual reduction in emissions for the average house constructed under the revised code, including both those that complied and did not comply.

Table 7-2
Average Annual Emissions Savings

	SO_x	NO_x	CO_2
Average Savings per House	4.21 lb/yr	3.39 lb/yr	3,689 lb/yr
Total Savings for New Houses	30.4 ton/yr	24.5 ton/yr	26,600 ton/yr
Note: Estimate of new houses is based on U.S. Census data for housing units authorized (14,442) in 2000.			

7.2 RECOMMENDATIONS

This subsection presents recommendations for improving code compliance and enforcement to increase the benefits provided by the code. This study has provided key insights into where the compliance and enforcement processes can be improved and the types of improvements that are needed.

7.2.1 Training and Information Dissemination

Because the market actor interviews indicated that the BBRS training had been a significant and effective source of code information in the past, we suggest that the BBRS institute additional training in the areas and on the topics identified later. Other types of information dissemination should be implemented as well and targeted at the topics and market actors that will be most affected to increase code compliance. The BBRS should work with respected professional organizations to train their members and help disseminate information.

Refresher training should be offered for code officials and others who have already been trained but need an update on the code and information about new technologies and practices. Training should be offered for code officials who missed the first round of training. Training should be implemented to improve consistency in how the code is enforced across jurisdictions. Training of builders should be timed, if possible, to occur in slow building seasons.

7.2.2 Messages, Information, and Materials

Probably one of the most important messages to be communicated to market actors is what the impacts are of not meeting the code and how often new houses fail to meet it. This study has shown that the overall compliance rate is less than 50% and all market actors should be made aware of this. Our analysis showed that energy savings differed substantially between houses that complied with the code and those that did not. Buyers, code officials, and builders need to be aware of impacts in terms of energy use and utility bills of not meeting the code. Messages and informational materials can be prepared from the data presented here that stress the consequences of houses that do not meet the energy code.

Information on good or exemplary practices and improved energy-efficiency technologies should be compiled and made available to builders and their contractors. Code officials also should be informed of these practices and technologies so that they can accept them under the code and communicate them to other code officials and builders.

Areas in which compliance has been poor, such as sealing of ducts, heating equipment sizing, and sealing of penetrations should be emphasized.

Tools should be developed to simplify compliance and enforcement. Two examples of recommended tools are standardized checklists to verify compliance and heating/cooling system efficiency and sizing checklists or sheets. In addition, the code language regarding sizing of combined space and water heating equipment should be clarified.

Information on the benefits of setting back thermostats during appropriate times should be compiled. We haven’t estimated the energy savings here, but other studies have been conducted that could provide estimated savings.

The development of a MacIntosh™-compatible version of MAS*check* should be explored.

Examine the feasibility of providing annual updates of the building code through the State Bookstore on searchable CD-ROMs. Consider making them available with an optional payment as part of contractor license renewal.

7.2.3 Targeting

Training and information dissemination should especially target builders. Their knowledge level appeared to be the least of key market actors and they are the most instrumental in ensuring that houses are built to the code. Because designers and suppliers appeared to be the best-informed groups, they could be used as information channels to reach builders.

Information and training on proper sizing of heating and cooling equipment should be targeted to contractors that install these systems. Decisions about equipment sizing are often made by these contractors, rather than the builder, and our onsite surveys showed that oversizing of heating equipment was very common. Equipment distributors might serve as an effective channel for educating these contractors.

Code officials also should be targeted to inform them about the frequency at which new houses fail to meet the code and the impacts of noncompliance on homebuyers.

Information should be targeted to homebuyers on the benefits of houses that meet code and things to look for in a new house to ensure that it complies. Homebuyers should be targeted with information on good operating practices, such as setting back the thermostat during unoccupied or sleeping periods.

Special compliance efforts should be directed at houses with oil heat—a much lower share of them complied with the code than houses heated with gas. Special efforts should be targeted at improving compliance in the coldest parts of the state also since compliance rates were considerably lower in these areas.

7.2.4 Practices and Procedures

Probably the most significant change that code officials can make in their procedures is to check construction practices against the original compliance documentation, usually the MAS*check* output, or require that compliance of the house as-built be verified, for example by requiring the MAS*check* run to be updated. Substantial differences occurred between the original compliance documents and the characteristics of houses as-built and it was insufficient to rely on the original documentation to ensure compliance. The standardized checklist mentioned earlier could be used to simplify compliance checking in the field.

Documentation in code compliance files should be improved. All building departments should establish practices to ensure that all materials are present for each house. Manufacturers' cut sheets on windows, doors, and heating/cooling equipment should be included in the files to improve compliance verification.

Builders should increase their use of foam sealants to reduce infiltration, apply mastic to seal ducts, and size heating equipment appropriately. All of theses changes could lead to significant improvements in energy efficiency.

Special attention should be directed to increasing the use of a more whole-building approach to the design, construction, and compliance process. In general, approaches are needed for improving communications between the builder (prime contractor) and the subcontractors and suppliers so that the new house is treated more as an integrated system. For example, decisions about heating equipment are often left to subcontractors and the equipment installed can vary considerably from what the designer or builder had planned during the design process. This can lead to noncompliance, or unnecessary expenses from installing more efficient equipment than required.

Builders should increase their use of higher insulation levels in floors and walls and use continuous insulation where appropriate to comply with the code.

The market for prescriptive approaches to compliance should be investigated further. It appeared that smaller builders might be more likely to use prescriptive packages if they understood them and their advantages better.

A ONSITE SURVEY INSTRUMENT

This appendix presents the instrument that was used to collect house characteristics through 186 onsite surveys. The instrument is organized into several sections and each section is described by the section title or introductory text. The MCxx variables are the MAS*check* values taken from the MAS*check* form if one was included in the building department files. The MSxx variables are those inputs to MAS*check* that we compiled based on the onsite survey data. The variable names are the same ones used in the data entry database.

1. GENERAL INFORMATION (GI)

GI1 - Owner Name ______________________________

GI2 - Name of individual present during on-site survey ______________________________

GI3 - Owner Address ______________________________

GI4 - City/State/Zip ______________________________

GI5 - Telephone Number ______________________________

GI6 - Building Permit Date ______________________________

GI7 - Completion Date (A - MONTH)____________ (B - YEAR)____________

GI8 - Occupancy Date (A - MONTH)____________ (B - YEAR)____________

GI9 - Purchase Price ______________________________

GI10 - Builder Contact Name ______________________________

GI11 - Builder Firm Name ______________________________

GI12 - Builder Phone Number ______________________________

GI13 - Was builder or homeowner an Energy Star Home participant?____ YES (1) ____ NO (2)

GI14 - Did they receive any gas utility heating equipment rebate? ____ YES (1) ____ NO (2)

GI15 – Is any HUD financing involved in the construction of this home? ____ YES (1) ____ NO (2)

2. BUILDING INFORMATION (BI) (determine on-site)

BI1 - One or two family home ____________

BI2 - Volume of Conditioned Space ____________ Cubic Feet

BI3 - Area of Conditioned Space ___________Square Feet

BI4 - Number of Bedrooms ____________________

BI5 - Floors On or Above Grade 1 – One 2 – Two 3 – Three 4 – Four 5 – Five

BI6 - Foundation type *1. Slab on Grade 2. Vented Crawl 3. Unvented Crawl Space 4.Conditioned Basement 5. Unconditioned basement 6. More than one type*

BI7 - Basement Actively Heated ___ YES (1) ___ NO (2)

BI8 - Basement Actively Cooled ___ YES (1) ___ NO (2)

BI9 - Front door Orientation (see below) ____________________

ORIENTATION
1. South
2. Southeast
3. East
4. Northeast
5. North
6. Northwest
7. West
8. Southwest

3. ENERGY CODE COMPLIANCE INFORMATION (EC)

EC1 - Method of Compliance
___ 1 - J5.0 Prescriptive Practice / Default Package
___ 2 - J6.0 Component Performance / Manual Trade-Off
___ 3 - J7.0 MAS*check* software
___ 4 - J8.0 Systems Approach / Total Energy Analysis
___ 5 - J9.0 Renewable Energy Resources
___ 6 - Method could not be determined (Run MAScheck)

EC2 - Compliance Method documentation provided to support compliance determination?

___ YES (1) ___ NO (2)

EC3 - Building plans contain required energy code information?

___ YES (1) ___ NO (2)

(Are insulation R-values, glazing U-values, heating/cooling/water equipment efficiency clearly marked on the building plans or specifications?)

4. PRESCRIPTIVE PACKAGE COMPLIANCE INFORMATION (PP)

PP1 - Correct prescriptive climate zone (determine from city/town HDD assignments) ____

PP2 - Prescriptive climate zone used by builder and approved by official (***if different***) ____

PP3 - Prescriptive package used is specified in building department files ___ YES (1) ___ NO (2)

PP4 - Prescriptive package used/assumed (A – KK, **SEE ATTACHED**) __________

PP5 - Specify package requirements in table below, verify on site.

If prescriptive package is assumed, leave the first data column blank, and record actual, observed values in the second column.

Building Element	***Minimum/Maximum Required (A)***	***Observed Values Meet or Exceed Actual Values (Y = 1/N = 2)? (B)***
PP51 – Glazing area		
PP52 – Maximum allowable % of glazing in gross wall area		
PP53 – Glazing U-Value		
PP54 – Ceiling R-Value		
PP55 – Wall R-Value		
PP56 – Floor R-Value		
PP57 – Basement R-Value		
PP58 – Slab R-Value		
PP59 – AFUE		

PP6 – Based on on-site verification of package requirements, does home __ PASS (1) __FAIL (2)

5. MASCHECK COMPLIANCE INFORMATION (MC)

If MAScheck compliance report is in building file, specify the inputs included in the compliance report in the table below ***(Attach photocopies of* Mascheck *forms whenever available.)*** :

	Net Area / Perimeter (A)	*Cavity R-Value* (B)	*Continuous R-Value* (C)	*Glazing/Door U-Value* (D)
MC11 - Ceilings				
MC12				
MC13				
MC14				
MC15				
MC21 - Walls				
MC22				
MC23				
MC24				
MC31 - Basement				
MC32				
MC41 - Doors				
MC42				
MC51 - Glazing				
MC52				
MC53				
MC54				
MC55				
MC61 - Floor R-Value				
MC62				
MC71 - Slab R-Value				
MC72				

MC81 - Heating Plant Type ____ BOILER (1) ____ FURNACE (2) ____ HEAT PUMP (3)

MC82 – If boiler/furnace, AFUE ___________ _____ Not applicable (97)

MC83 – If heat pump, HSPF ___________ _____ Not applicable (97)

MC84 – If heat pump, SEER ___________ _____ Not applicable (97)

MC91 - Maximum UA noted on Compliance Report ______________

MC92 - “Your Home” UA noted on Compliance Report ______________

MC93 - No MAScheck documentation provided ___________ (1)

Specify MAScheck inputs from on-site survey (MS)

	Net Area / Perimeter (A)	***Cavity R-Value*** (B)	***Continuous R-Value*** (C)	***Glazing/Door U-Value*** (D)
MS11 - Ceilings				
MS12				
MS13				
MS14				
MS15				
MS21 - Walls				
MS22				
MS23				
MS24				
MS31 - Basement				
MS32				
MS41 - Doors				
MS42				
MS51 - Glazing				
MS52				
MS53				
MS54				
MS55				
MS61 - Floor R-Value				
MS62				
MS71 - Slab R-Value				
MS72				

MS81 - Heating Plant Type ___ BOILER (1) ____ FURNACE (2) ____ HEAT PUMP (3)

MS82 – If boiler/furnace, AFUE ________ _____ Not applicable (97)

MS83 – If heat pump, HSPF ________ _____ Not applicable (97)

MS84 – If heat pump, SEER ________ _____ Not applicable (97)

MS91 - Maximum UA calculated after on site ___________

MS92 - “Your Home” UA calculated after on site ___________

MS93 _______ PASS (1) _______ FAIL (2)

MS94 - Do observed, on site values differ by more than 10% from the values in the compliance report for:

A - Areas/Perimeters ____ YES (1) ____ NO (2)

B - Insulation levels ____ YES (1) ____ NO (2)

C - Glazing/Door U-Values ____ YES (1) ____ NO (2)

MS95 - Does observed, on site value differ by more than 5% from the value in the compliance report for:

AFUE ____ YES (1) ____ NO (2)

6. ADDITIONAL ENERGY CODE GENERAL COMPLIANCE REQUIREMENTS (AEC)

AEC1 - Air infiltration mitigation measures are properly installed? ____ YES (1) ____ NO (2)

Joints, penetrations, and all other such openings in the building envelope that are sources of air leakage must be sealed (wiring & plumbing penetrations, kneewall transitions, chases, dropped soffits, plates, sills, etc.) When installed in the building envelope, recessed lighting fixtures shall meet one of the following requirements:

1) Type IC rated, manufactured with no penetrations between the inside and the outside of the recessed fixture and ceiling cavity and sealed or gasketed to prevent air leakage into the unconditioned space.
2) Type IC rated, in accordance with Standard ASTM E 283, with no more than 2.0 cfm (0.944 L/s) air movement from the conditioned space to the ceiling cavity. The lighting fixture shall have been tested at 75 PA or 1.57 lbs/ft2 pressure difference and shall be labeled.

AEC2 - Duct systems are adequately sealed? ____ YES (1) ____ NO (2)

Allowable exceptions include:

1) Lengthwise snap-lock joints are tight fitting
2) Flex duct connections properly installed using tension straps

AEC3 - Duct systems outside conditioned spaces are fully insulated? ____ YES (1) ____ NO (2)

AEC4 - HVAC hot water pipes fully insulated? ____ YES (1) ____ NO (2)

Allowable exceptions include pipes within HVAC equipment and piping installed in basements having insulated walls

AEC5 - Each HVAC system has its own thermostat? ____ YES (1) ____ NO (2)

AEC6 - Each HVAC zone/floor has a readily accessible manual or automatic means to partially restrict or shut off the input to each zone or floor?

____ YES (1) ____ NO (2)

AEC7 - Vapor retarder present? ____ YES (1) ____ NO (2)

Allowable exception: ceilings are not required to have a vapor retarder if the attic has ventilation with a net free area of at least 1:150 ratio of ceiling area.

7. ENVELOPE DATA – FRAME AND BRICK VENEER WALLS (EFW)

BY WALL SEGMENT:	Segment (A)	Segment (B)	Segment (C)	Segment (D)	Segment (E)
EFW1 – Gross wall area					
EFW2 - Wall Location (see below)					
EFW3 – Orientation (see below)					
EFW4 – Cavity wall insulation R-value					
EFW5 – Cavity wall insulation thickness in inches					
EFW6 – Continuous wall insulation R-value					
EFW7 – Continuous wall insulation thickness					
EFW8 – Stud Spacing					
EFW9 – Exterior wall color(1 – light 2 – med 3 – dark)					

BY WALL SEGMENT:	Segment (F)	Segment (G)	Segment (H)	Segmentt (I)	Segment (J)
EFW1 – Gross wall area					
EFW2 – Wall Location (see below)					
EFW3 – Orientation (see below)					
EFW4 – Cavity wall insulation R-value					
EFW5 – Cavity wall insulation thickness in inches					
EFW6 - Continuous wall insulation R-value					
EFW7 - Continuous wall insulation thickness					
EFW8 - Stud Spacing in inches					
EFW9 - Exterior wall color (1 – light 2 – med 3 – dark)					

Wall is located between:

1. Conditioned area and ambient conditions
2. Conditioned area and attic, garage, or vented crawl space
3. Conditioned area and unconditioned basement or unvented crawl
4. *Unconditioned area and ambient conditions or vented crawl space*

ORIENTATION

1. South
2. Southeast
3. East
4. Northeast
5. North
6. Northwest
7. West
8. Southwest

8. ENVELOPE DATA – MASONRY WALLS (EMW)

BY WALL SEGMENT:	Segment (A)	Segment (B)	Segment (C)	Segment (D)	Segment (E)
EMW1 - Gross wall area					
EMW2 - Wall Location (see below)					
EMW3 - Orientation (see below)					
EMW4 - Batt insulation R-Value					
EMW5 - Rigid insulation R-Value					
EMW6 - Wall type (1– block 2– brick 3– concrete)					
EMW7 - Wall thickness in inches					
EMW8 - Exterior wall color (1- light 2- med 3- dark)					

BY WALL SEGMENT:	Segment (F)	Segment (G)	Segment (H)	Segment (I)	Segment (J)
EMW1 - Gross wall area					
EMW2 - Wall Location (see below)					
EMW3 - Orientation (see below)					
EMW4 - Batt insulation R-Value					
EMW5 - Rigid insulation R-Value					
EMW6 - Wall type (1 – block 2 – brick 3 – concrete)					
EMW7 - Wall thickness in inches					
EMW8 - Exterior wall color (1- light 2- med 3- dark)					

Wall is located between:

1. Conditioned area and ambient conditions
2. Conditioned area and attic, garage, or vented crawl space
3. Conditioned area and unconditioned basement or unvented crawl
4. Unconditioned area and ambient conditions or vented crawl space

Orientation

1. South
2. Southeast
3. East
4. Northeast
5. North
6. Northwest
7. West
8. Southwest

9. ENVELOPE DATA – FOUNDATION WALLS BELOW GRADE (EFB)

BY CONSTRUCTION TYPE:	Segment (A)	Segment (B)	Segment (C)	Segment (D)	Segment (E)
EFB1 - Wall type (1 – brick 2 – block 3 – concrete)					
EFB2 - Wall thickness in inches					
EFB3 – Length in feet					
EFB4 - Depth below grade in feet					
EFB5 - Wall height in inches					
EFB6 - Wall location (see below)					
EFB7 - Batt insulation R-Value					
EFB8 - Rigid insulation R-Value					
EFB9 - Fully insulated above grade (1 – yes 2 – no)					

Wall is located between:
1. Conditioned area and earth
2. Unconditioned area and earth

10. ENVELOPE DATA – FRAME FLOORS ABOVE UNCONDITIONED SPACE (EFF)

BY FLOOR SECTION:	Section (A)	Section (B)	Section (C)	Section (D)	Section (E)
EFF1 - Floor area					
EFF2 - Insulation R-Value					
EFF3 - Floor location (see below)					

Floor is located between:
1. Conditioned area and unconditioned garage
2. Conditioned area and unconditioned basement or crawl space
3. Conditioned area and ambient conditions

11. ENVELOPE DATA – RIM AND BAND JOISTS (ERJ)

BY SECTION:	Section (A)	Section (B)	Section (C)	Section (D)	Section (E)
ERJ1 - Area					
ERJ2 - Joist location (see below)					
ERJ3 - Rigid insulation R-value					
ERJ4 - Batt insulation R-value					

Joist is located between:
1. *Conditioned area and ambient conditions*
2. *Conditioned area and attic, garage, or vented crawl space*
3. *Conditioned area and unconditioned basement or unvented crawl*
4. *Unconditioned area and ambient conditions or vented crawl space*

12. ENVELOPE DATA – SLAB FLOOR (ESF)

BY SECTION:	Section (A)	Section (B)	Section (C)	Section (D)	Section (E)
ESF1 - Floor area					
ESF2 - Exposed perimeter (Less than 12" b.g)					
ESF3 - Total perimeter					
ESF4 – Perimeter insulation R-value					
ESF5 - Under slab insulation R-value					
ESF6 - Depth below grade in feet					
ESF7 - Insulation to top of slab? (1 – Yes 2 – No 98 – Don't Know					
ESF8 - Width of insulation under slab (as able to determine from photos, etc.)					

13. ENVELOPE DATA – WINDOWS (EW)

BY WINDOW TYPE / WALL ORIENTATION	Type (A)	Type (B)	Type (C)	Type (D)	Type (E)
EW1 – Window area					
EW2 – Window wall segment (see pages 5&6)					
EW3 – Orientation (see below)					
EW4 – Frame type (see below)					
EW5 – Glazing type (see below)					
EW6 – (1) Operable **OR** (2) Fixed					
EW7 - U-Value					
EW8 - U-Value type (1 – Confirmed 2 – Default)					

BY WINDOW TYPE / WALL ORIENTATION	Type (F)	Type (G)	Type (H)	Type (I)	Type (J)
EW1 - Window area					
EW2 - Window wall segment (see pages 5&6)					
EW3 - Orientation (see below)					
EW4 - Frame type (see below)					
EW5 - Glazing type (see below)					
EW6 – (1) Operable **OR** (2) Fixed					
EW7 - U-Value					
EW8 - U-Value type (1 – Confirmed 2 – Default)					

ORIENTATION
1. South
2. Southeast
3. East
4. Northeast
5. North
6. Northwest
7. West
8. Southwest

FRAME TYPE
1. Metal
2. Metal with break
3. Wood
4. Vinyl
5. Fiberglass

GLAZING TYPE
1. Single
2. Single with storm
3. Double
4. Triple
5. Double with Low-E
6. Double with Low-E and Argon
7. Heat Mirror 88
8. Double HM88 with Krypton
9. Double Low E with Krypton
10. Triple Low E with Argon
11. Triple Low E with Krypton
12. Other

BY WINDOW TYPE / WALL ORIENTATION	Type (K)	Type (L)	Type (M)	Type (N)	Type (O)
EW1 - Window area					
EW2 - Window wall segment (see pages 5&6)					
EW3 - Orientation (see below)					
EW4 - Frame type (see below)					
EW5 - Glazing type (see below)					
EW6 – (1) Operable **OR** (2) Fixed					
EW7 - U-Value					
EW8 - U-Value type (1 – Confirmed 2 – Default)					

ORIENTATION
1. South
2. Southeast
3. East
4. Northeast
5. North
6. Northwest
7. West
8. Southwest

FRAME TYPE
1. Metal
2. Metal with break
3. Wood
4. Vinyl
5. Fiberglass

GLAZING TYPE
1. Single
2. Single with storm
3. Double
4. Triple
5. Double with Low-E
6. Double with Low-E and Argon
7. Heat Mirror 88
8. Double HM88 with Krypton
9. Double Low E with Krypton
10. Triple Low E with Argon
11. Triple Low E with Krypton
12. Other

14. ENVELOPE DATA – DOORS (ED)

BY WALL SEGMENT/ORIENTATION	Type (A)	Type (B)	Type (C)	Type (D)	Type (E)
ED1 - Door area					
ED2 - Door wall segment (from pages 5 & 6)					
ED3 - Wall Orientation (see below)					
ED4 - Door type (see below)					
ED5 - Storm door type (see below)					
ED6 – U-Value					
ED7 – U-Value (Confirmed = 1 **OR** Default = 2)					

ORIENTATION
1. South
2. Southeast
3. East
4. Northeast
5. North
6. Northwest
7. West
8. Southwest

DOOR TYPE
1. Steel with Insulated Core
2. Wood w/ 7/16" panel s
3. Wood hollow core
4. Wood solid core
5. Wood w/ 1 1/8" panel s

STORM DOOR TYPE
1 = Wood
2 = Metal
3 = None

15. ENVELOPE DATA - CEILING / ROOF (ECR)

BY CEILING SEGMENT	Segment (A)	Segment (B)	Segment (C)	Segment (D)	Segment (E)
ECR1 - Gross area					
ECR2 - Rigid insulation R-Value					
ECR3 - Loose fill or batt insulation R-value					
ECR4 - Radiant barrier present? (1 – yes 2 – No)					
ECR5 - Ceiling type (see below)					
ECR6 - Rafter spacing					
ECR7 - Roof color (1 – light 2 – medium 3 – dark)					

CEILING TYPE
1. Ceiling with attic above
2. Cathedral ceiling / no attic
3. Flat roof

16. ENVELOPE DATA – SKYLIGHTS (ES)

BY ORIENTATION	Type (A)	Type (B)	Type (C)	Type (D)	Type (E)
ES1 – Area					
ES2 – Pitch					
ES3 – Glazing type (see below)					
ES4 – Frame type (see below)					
ES5 – (1) Operable OR (2) Fixed					
ES6 – Window U-Value (see table)					
ES7 – Orientation					
ES8 – Skylight ceiling segment (From 15)					

GLAZING TYPE
1. Single
2. Single with storm
3. Double
4. Triple
5. Double with Low-E
6. Double with Low-E and Argon
7. Heat Mirror 88
8. Double HM88 with Krypton
9. Double Low E with Krypton
10. Triple with Low E
11. Triple Low E with Argon
12. Triple Low E with Krypton
13. Other

FRAME TYPE
1. Metal
2. Metal with break
3. Wood
4. Vinyl
5. Fiberglass

ORIENTATION
1. South
2. Southeast
3. East
4. Northeast
5. North
6. Northwest
7. West
8. Southwest

Pitch is described as the rise in feet out of a standard run of 12 feet. For example, the value 5 would indicate a rise of 5 in a run of 12; or a 5/12 pitch.

17. HVAC DATA – HEATING (HVH)

HVH1 - Number of central systems in home __________

BY FUEL AND TYPE	Unit (A)	Unit (B)	Unit (C)	Unit (D)	Unit (E)
HVH2 – Fuel (see below)					
HVH3 – System Type (see below)					
HVH4 – System capacity (Btu/hr) Output					
HVH5 – System efficiency (AFUE or HSPF)					
HVH6 – Make					
HVH7 – Model number					
HVH8 – System location (see below)					

FUEL
1. Oil
2. Gas
3. Propane
4. Electric
5. Wood/Coal

SYSTEM TYPE
1. Forced Warm Air
2. Forced Hot Water
3. Steam
4. Electric Baseboard
5. Electric Radiant
6. Air to Air Heat Pump
7. Ground Source Heat Pump
8. Hydro Air

SYSTEM LOCATION
1. Conditioned Space
2. Unconditioned Space

HVH9 - Supplementary heating type (wood=1, space heaters=2, solar = 3) __________

HVH10 - Estimated % of heating from primary system __________

HVH11 - Total number of zones __________

HVH12 - Total number of thermostats – manual or auto setback __________

HVH13 - Number of the above that are programmable __________

HVH14 - Thermostat and occupancy schedules for winter heating:

	6AM-8 AM (A)	8AM – 5PM (B)	5PM – 11PM (C)	11PM – 6AM (D)
HVH141 - Heating Thermostat				
HVH142 - # People Home in winter				

18. HVAC DATA – COOLING (HVC)

HVC1 - Number of central systems in home __________

	Unit (A)	*Unit (B)*	*Unit (C)*	*Unit (D)*	*Unit (E)*
HVC2 - System capacity in Btu's/hour output					
HVC3 – System efficiency (SEER)					
HVC4 - Make					
HVC5 - Model number					
HVC6 - System location 1 – conditioned 2 –unconditioned					

HVC7 - Number of room air conditioners _____

HVC8 - Whole house ventilation fan ___ YES (1) ______ NO (2)

HVC9 - Thermostat and occupancy schedules for summer cooling:

	6AM-8 AM (A)	8AM – 5PM (B)	5PM – 11PM (C)	11PM – 6AM (D)
HVC91 - Cooling Thermostat				
HVC92 - # People Home in summer				

19. DOMESTIC HOT WATER (DHW)

BY FUEL AND TYPE	Unit (A)	Unit (B)	Unit (C)	Unit (D)	Unit (E)
DHW1 – Number of tanks					
DHW2 – Fuel (see below)					
DHW3 – Type (see below)					
DHW4 – Capacity (gallons)					
DHW5 – Tank location (see below)					
DHW6 – Energy factor					
DHW7 – Make					
DHW8 – Model number					
DHW9 – Extra tank R-value					

FUEL
1. Oil
2. Gas
3. Propane
4. Electric
5. Wood/Coal

UNIT TYPE
1. Conventional tank
2. High efficiency tank
3. Indirect fired
4. Tankless coil
3. Instantaneous
5. Heat pump

SYSTEM LOCATION
1. Conditioned Space
2. Unconditioned Space

20. AIR INFILTRATION/VENTILATION (AIV)

AIV1 - Natural infiltration rate - Air changes/hour (natural) ____________

AIV2 - Measured infiltration rate - CFM_{50} ____________

Mech. Ventilation	Fan 1 (A)	Fan 2 (B)	Fan 3 (C)	Fan 4 (D)	Fan 5 (E)	ERV – 1 (F)	ERV – 2 (G)	Exhaust Only –1 (H)	Exhaust Only –2 (I)
AIV3 - Type/Location									
AIV4 – Control Type									
AIV5 – Nameplate Flow									
AIV6 – Vented Outdoors (1 – Yes 2 – No)									
AIV7 – Make									
AIV8 – Model									
AIV9 – HRV Efficiency									

Type / location: 1 – Bath exhaust fan 2 – Kitchen exhaust fan 3 – Other point exhaust fan 4 - ERV 5 – Exhaust Only

Control Type: 1 – On /off switch 2 – Twist timer 3 – T ime clock 4 – Dehumidistat 5 – Occupancy sensor 6 – Runs continuously

AIV10 - Is kitchen fan set up in recirculating ductless configuration? ______ YES (1) _____ NO (2)

AIV11 - Presence of passive air inlets ______ YES (1) _____ NO (2)

AIV12 – Does all ventilation ductwork properly exit the house (i.e., bath fans, ducted kitchen fans, clothes dryer, etc.)? ______ YES (1) _____ NO (2)

If not, circle the area type(s) where ducts terminate: (1) living space (2) attic (3) basement (4) interstitial

21. AIR INFILTRATION – DUCT LEAKAGE (AID)

First System Tested (typically system with greatest potential for leakage to the outside.)

AID1 - Total System Flow - CFM_{25} ___________

AID2 - Leakage to the outside - CFM_{25} ___________

Second System tested (if any.)

AID3 - Total System Flow - CFM_{25} ___________

AID4 - Leakage to the outside - CFM_{25} ___________

Duct insulation	Attic (A)	Crawlspace (B)	Unconditioned Basement (C)
AID5 - Duct area			
AID6 - Duct insulation R-value			
AID7 - Duct insulation condition			

(Condition descriptors: 1 - **E**ffective 2 - **P**artially effective 3 - **I**nadequate or missing)

22. INTERNAL GAINS (IG)

IG1 - Number of refrigerators in conditioned space ___________

IG2 - Number of freezers in conditioned space ___________

IG3 - Cooking fuel ___________

IG4 - Number of meals per week ___________

IG5 - Dryer fuel ___________

IG6 - Number of loads dried per week ___________

IG7 - Dishwasher loads per week ___________

FUEL
1. Gas
2. Electric
3. Propane
4. Other

23. SURVEY DOCUMENATION (SD)

SD1 - Auditor name ____

SD2 - Date surveyed ____

Office use only:	Q.C. initials		Date	/ /

Appliance and Lighting Data Collection Forms for Massachusetts BBRS Code Compliance Study - JMC Add-on

APPLIANCES

Refrigerators (AR)

AR1 - Total number of refrigerators in the house _______

	Manufacturer (A)	Model # (B)	Size - ft³ (C)	Vintage: 1 – New 2 - Used (D)	Operation: 1 – Continuous 2 – Intermittent (E)
AR2					
AR3					
AR4					
AR5					

Room Air Conditioners (AAC)

AAC1 - Total number of RAC units in the house _______

	Manufacturer (A)	Model # (B)	Size - Btuh (C)	Vintage 1 – New 2 – Used (D)	
AAC2					
AAC3					
AAC4					
AAC5					

Dishwashers (AD)

AD1 - Total number of dishwashers in the house _______

	Manufacturer (A)	Model # (B)		Vintage 1 – New 2 – Used (D)	
AD2					
AD3					

Clothes Washers (ACW)

ACW1 - Total number of clothes washers in the house _______

	Manufacturer (A)	Model # (B)	Type 1 – Resource Efficient 2 - Standard (C)	Vintage 1 – New 2 – Used (D)	
ACW2					
ACW3					

Lighting (LI / LE)

	Location (A)	Fixture Type (B)	Wattage (C)	# Lamps/ Fixture (D)	Control (E)	Hours Used/Day (F)	Quantity (G)
INTERIOR FIXTURES (record hours used if timer controlled hard wired)							
LI1							
LI2							
LI3							
LI4							
LI5							
LI6							
LI7							
LI8							
LI9							
LI10							
LI11							
LI12							
LI13							
LI14							
LI15							
LI16							
LI17							
LI18							
LI19							
LI20							
LI21							
LI22							
LI23							
LI24							
LI25							
LI26							
LI27							
LI28							
LI29							
LI30							
LI31							
EXTERIOR FIXTURES – (record hours of use for all)							
LE1							
LE2							
LE3							
LE4							
LE5							
LE6							
LE7							
LE8							
LE9							
LE10							
LE11							
LE12							
LE13							
LE14							

RECORD HOURS OF USE FOR ALL EXTERIOR AND ONLY TIMER CONTROLLED HARD WIRED INTERIOR FIXTURES.

LIGHTING AND APPLIANCE CODES

Location of Fixture	Code	Fixture Type	Code	Lighting Controls	Code
1 Bedroom	B	1 Compact Fluorescent	C	1 On/Off	O
2 Dining room	D	2 Fluorescent Tube	F	2 Dimmer/Rheostat	D
3 Living room	L	3 Incandescent	I	3 Motion Sensor	M
4 Kitchen	K	4 Halogen	H	4 Photo-cell	P
5 Bathroom	T	5 High Pressure Sodium	HS	5 Combined motion & photo	C
6 Hallway	H	6 Low Pressure Sodium	LS	6 Timer control	T
7 Family room/den	F	7 Mercury Vapor	MV		
8 Office	O	8 Metal Halide	MH		
9 Enclosed porch/entry	P				
10 Basement	X				
11 Garage	G				
12 Other	M				

Appliance Manufacturer Codes (AMC)

Manufacturer	*Code*	*Manufacturer*	*Code*
1 Admiral	AD	22 Kelvinator	KL
2 Airtemp	AT	23 Kenmore	KN
3 Amana	AM	24 Kitchen Aid	KA
4 Asko	AS	25 Magic Chef	MC
5 Bosch	B	26 Maytag	MT
6 Carrier	C	27 Miele	ML
7 Comfort-Aire	CA	28 Montgomery Ward	MW
8 Crosley	CR	29 Panasonic	P
9 Emerson	EM	30 Quasar	QS
10 Equator	EQ	31 Quiteline	QT
11 Fedders	FD	32 RCA	RC
12 Fisher & Paykel	FP	33 Roper	R
13 Frigidaire	FG	34 Samsung	SM
14 Friedrich	FR	35 Sanyo	SN
15 GMC	GM	36 Sharp	SH
16 General Electric	GE	37 Splendide	SP
17 Gibson	GB	38 Staber	ST
18 Hampton Bay	HB	39 Tappan	TP
19 Hotpoint	HT	40 Whilrpool	WP
20 Inglis	I	41 White-Westinghouse	WW
21 Jennair	J		

B ONSITE SURVEY DATA

This appendix presents a summary of the detailed results from the onsite surveys. The numerical variables are presented first, followed by the categorical variables.

The variable name is shown in the first column, followed by a description of the variable. Most of the variable names are included in the onsite data collection instrument (see Appendix A). The variables that are not from the data collection instrument are calculated variables based on the onsite data (e.g., ms92_91, which is MS92/MS91 and is a measure of compliance with the code) or data calculated from the DOE-2 building analysis runs (e.g., SVHVACEL, which is the annual HVAC electricity savings).

The third column indicates the number of houses in our sample for which we had data on each variable. The fourth column takes into account the weighting used to define our sample and, for many variables, this weighting can be used to estimate the mean value for the population of new houses.

The fifth column presents the estimated mean population value for the variable. The next column presents the standard error of the mean. The last two columns present the minimum and maximum values in the sample. In the case of categorical variables, the value in the mean column is the estimated population proportion that falls into each category.

Variable	Question and response	# of Sample New Houses	% of Population of New Houses	Estimate	Standard Error of Estimate	Minimum	Maximum
Numerical Variables							
GI9	Purchase Price	159	85.7%	337472.4	25833.00	84500	933000
BI2	Volume of Conditioned Space (Cubic Feet)	186	100.0%	20945.2	986.14	6030	51127
BI3	Area of Conditioned Space (Square Feet)	186	100.0%	2538.1	109.63	804	5840
BI4	Number of Bedrooms	186	100.0%	3.5	0.08	1	6
MS11A	Ceilings - Area / Perimeter	186	100.0%	1493.4	66.81	80	3826
MS11B	Ceilings - Cavity R-Value	186	100.0%	31.5	0.34	19	49
MS11C	Ceilings - Continuous R-Value	3	2.0%	3.8	0.84	1	6
MS12A	Ceilings - Area / Perimeter	24	12.2%	368.8	46.43	49	805
MS12B	Ceilings - Cavity R-Value	24	12.2%	29.7	1.06	19	41
MS12C	Ceilings - Continuous R-Value	1	0.5%	1.0	0.00	1	1
MS21A	Walls - Area / Perimeter	186	100.0%	1999.0	62.43	716	3531
MS21B	Walls - Cavity R-Value	186	100.0%	14.1	0.28	11	19.25
MS21C	Walls - Continuous R-Value	6	3.5%	2.7	0.22	1.3	3
MS22A	Walls - Area / Perimeter	13	6.1%	344.2	37.37	116	720
MS22B	Walls - Cavity R-Value	13	6.1%	12.6	0.68	10	19
MS22C	Walls - Continuous R-Value	0	0.0%				
MS23A	Walls - Area / Perimeter	1	0.5%	312.0	0.00	312	312
MS23B	Walls - Cavity R-Value	1	0.5%	13.0	0.00	13	13
MS23C	Walls - Continuous R-Value	0	0.0%				
MS31A	Basement - Area / Perimeter	8	4.6%	1246.6	99.80	928	1608
MS31B	Basement - Cavity R-Value	8	4.6%	12.8	0.18	11	13
MS31C	Basement - Continuous R-Value	0	0.0%				
MS32A	Basement - Area / Perimeter	1	0.5%	39.8	0.00	39.83	39.83
MS32B	Basement - Cavity R-Value	1	0.5%	7.0	0.00	7	7
MS32C	Basement - Continuous R-Value	0	0.0%				

Variable	Question and response	# of Sample New Houses	% of Population of New Houses	Estimate	Standard Error of Estimate	Minimum	Maximum
MS41A	Doors - Area / Perimeter	186	100.0%	43.3	1.65	10.2	168
MS41D	Doors - Glazing/Door U-Value	186	100.0%	0.354	0.00	0.35	0.47
MS42A	Doors - Area / Perimeter	18	9.6%	32.6	6.31	12.56	110.06
MS42D	Doors - Glazing/Door U-Value	18	9.6%	0.371	0.01	0.35	0.4
MS51A	Glazing - Area / Perimeter	186	100.0%	203.1	14.81	1.32	953
MS51D	Glazing - Glazing/Door U-Value	186	100.0%	0.438	0.01	0.31	0.92
MS52A	Glazing - Area / Perimeter	169	91.8%	121.5	10.96	3.08	736.43
MS52D	Glazing - Glazing/Door U-Value	168	91.3%	0.401	0.01	0.33	1.3
MS53A	Glazing - Area / Perimeter	75	40.6%	95.6	20.50	2.5	769.88
MS53D	Glazing - Glazing/Door U-Value	75	40.6%	0.728	0.07	0.33	5.6
MS54A	Glazing - Area / Perimeter	10	5.7%	32.0	9.96	0.42	84
MS54D	Glazing - Glazing/Door U-Value	10	5.7%	0.481	0.05	0.33	0.98
MS55A	Glazing - Area / Perimeter	2	1.2%	23.5	5.24	12	29
MS55D	Glazing - Glazing/Door U-Value	2	1.2%	0.410	0.01	0.4	0.43
MS61A	Floor R-Value - Area / Perimeter	183	98.4%	1268.9	51.78	63.5	4053
MS61B	Floor R-Value - Cavity R-Value	183	98.4%	18.6	0.60	0	30
MS61C	Floor R-Value - Continuous R-Value	3	2.0%	3.3	0.97	0	5.25
MS62A	Floor R-Value - Area / Perimeter	96	52.4%	288.0	36.49	12	1506
MS62B	Floor R-Value - Cavity R-Value	96	52.4%	26.3	0.66	0	30
MS62C	Floor R-Value - Continuous R-Value	0	0.0%				
MS63A	Floor R-Value - Area / Perimeter	4	1.9%	322.8	180.56	15	967
MS63B	Floor R-Value - Cavity R-Value	4	1.9%	10.6	6.10	0	30
MS63C	Floor R-Value - Continuous R-Value	1	0.5%		0.00	0	0
MS71A	Slab R-Value - Area / Perimeter	22	13.1%	141.6	38.52	18	1030
MS71B	Slab R-Value - Cavity R-Value	14	9.0%	22.3	3.83	0	30
MS71C	Slab R-Value - Continuous R-Value	2	1.1%	10.0	0.00	10	10
MS82	If boiler/furnace, AFUE	186	100.0%	0.855	0.01	0.8	0.946

Variable	Question and response	# of Sample New Houses	% of Population of New Houses	Estimate	Standard Error of Estimate	Minimum	Maximum
MS83	If heat pump, HSPF	0	0.0%				
MS84	If heat pump, SEER	0	0.0%				
MS91	Maximum UA calculated after on site	186	100.0%	448.6	18.46	177	1015
MS92	Your Home UA calculated after on site	186	100.0%	470.2	22.09	182	1366
ms92_91	Your Home/Max UA calculated after on site	186	100.0%	1.048	0.02	0.763	1.982
ES1A	Area	58	29.8%	15.6	1.23	4	45
ES2A	Pitch	58	29.8%	8.6	0.30	4	12
ES6A	Window U-Value	58	29.8%	0.903	0.02	0.42	1.3
ES1B	Area	9	4.4%	14.3	2.23	3.33	20
ES2B	Pitch	9	4.4%	7.7	0.42	6	9
ES6B	Window U-Value	9	4.4%	0.934	0.02	0.87	1.07
ES1C	Area	1	0.5%	14.7	0.00	14.67	14.67
ES2C	Pitch	1	0.5%	9.0	0.00	9	9
ES6C	Window U-Value	1	0.5%	0.92	0.00	0.92	0.92
HVH4A	System capacity (Btu/hr) Output	185	99.5%	102855.9	3088.24	42000	242000
HVH5A	System efficiency (AFUE or HSPF)	186	100.0%	0.853	0.01	0.8	0.946
HVH4B	System capacity (Btu/hr) Output	27	14.9%	67474.6	3026.23	32000	113000
HVH5B	System efficiency (AFUE or HSPF)	27	14.9%	0.881	0.01	0.8	0.938
HVH4C	System capacity (Btu/hr) Output	1	0.5%	60000.0	0.00	60000	60000
HVH5C	System efficiency (AFUE or HSPF)	1	0.5%	0.800	0.00	0.8	0.8
HVH10	Estimated % of heating from primary system	186	100.0%	1.0	0.00	0.5	1
HVH11	Total number of zones	185	99.6%	2.2	0.11	1	6
HVH12	Total number of thermostats - manual or auto setback	186	100.0%	2.2	0.10	1	6
HVH13	Number of the above that are	185	99.5%	0.3	0.07	0	4

Variable	Question and response	# of Sample New Houses	% of Population of New Houses	Estimate	Standard Error of Estimate	Minimum	Maximum
	programmable						
HVH14_1A	Heating Thermostat: 6AM-8AM	185	99.3%	67.8	0.23	60	76
HVH14_2A	# People Home in winter: 6AM-8AM	184	98.8%	3.1	0.08	1	6
HVH14_1B	Heating Thermostat: 8AM-5PM	185	99.3%	67.3	0.26	50	73
HVH14_2B	# People Home in winter: 8AM-5PM	182	97.7%	1.4	0.08	0	6
HVH14_1C	Heating Thermostat: 5PM-11PM	185	99.3%	68.3	0.30	18	74
HVH14_2C	# People Home in winter: 5PM-11PM	184	98.8%	3.1	0.09	0	6
HVH14_1D	Heating Thermostat: 11PM-6AM	185	99.3%	66.0	0.28	55	72
HVH14_2D	# People Home in winter: 11PM-6AM	184	98.8%	3.2	0.09	1	6
HVC1	Number of central systems in home	159	85.9%	1.03	0.10	0	4
HVC2A	System capacity in Btu's/hour output	103	55.4%	40543.8	1313.66	17000	60000
HVC3A	System efficiency (SEER)	37	19.3%	10.3	0.10	10	12
HVC2B	System capacity in Btu's/hour output	48	25.1%	33475.3	1265.33	23000	60000
HVC3B	System efficiency (SEER)	11	6.1%	10.2	0.13	10	12
HVC2C	System capacity in Btu's/hour output	6	3.0%	33232.5	4848.75	18000	48000
HVC3C	System efficiency (SEER)	2	1.6%	10.0	0.00	10	10
HVC2D	System capacity in Btu's/hour output	1	0.5%	18000.0	0.00	18000	18000
HVC3D	System efficiency (SEER)	0	0.0%				
HVC7	Number of room air conditioners	174	93.7%	0.2	0.04	0	2
HVC9_1A	Cooling Thermostat: 6AM-8AM	78	41.7%	71.8	0.84	0	80
HVC9_2A	# People Home in summer: 6AM-8AM	86	46.2%	3.1	0.13	1	6
HVC9_1B	Cooling Thermostat: 8AM-5PM	81	43.7%	72.0	0.85	0	82
HVC9_2B	# People Home in summer: 8AM-5PM	86	46.1%	1.7	0.12	0	6
HVC9_1C	Cooling Thermostat: 5PM-11PM	84	45.3%	72.7	0.39	62	80
HVC9_2C	# People Home in summer: 5PM-11PM	87	46.7%	3.0	0.15	0	6
HVC9_1D	Cooling Thermostat: 11PM-6AM	79	42.2%	73.0	0.46	62	82
HVC9_2D	# People Home in summer: 11PM-6AM	87	46.7%	3.1	0.13	1	6

Variable	Question and response	# of Sample New Houses	% of Population of New Houses	Estimate	Standard Error of Estimate	Minimum	Maximum
DHW1A	Number of tanks	186	100.0%	1.0	0.01	1	2
DHW4A	Capacity (gallons)	150	81.8%	54.7	1.99	20	120
DHW6A	Energy factor	103	55.5%	0.603	0.01	0.48	0.93
DHW9A	Extra tank R-value	5	2.2%	8.5	1.71	5	16
DHW1B	Number of tanks	2	1.5%	1.0	0.00	1	1
DHW4B	Capacity (gallons)	2	1.5%	40.2	4.41	36	50
DHW6B	Energy factor	1	0.5%	0.5	0.00	0.53	0.53
DHW9B	Extra tank R-value	0	0.0%				
AIV1	Natural infiltration rate - Air changes/hour	184	99.2%	0.342	0.01	0.1	1.09
AIV2	Measured infiltration rate - CFM50	184	99.2%	2464.0	94.50	750	7105
AIV5A	Nameplate Flow - Fan 1	179	96.6%	66.8	3.74	50	400
AIV5B	Nameplate Flow - Fan 2	175	93.8%	58.7	2.26	50	200
AIV5C	Nameplate Flow - Fan 3	101	54.6%	117.4	13.76	50	1000
AIV5D	Nameplate Flow - Fan 4	18	10.0%	174.3	31.81	50	400
AIV5E	Nameplate Flow - Fan 5	2	1.1%	881.9	270.99	400	1200
AIV5F	Nameplate Flow - ERV1	1	0.5%	223.0	0.00	223	223
AID1	First System Tested: Total System Flow - CFM25	22	11.3%	849.5	25.77	585	1147
AID2	First System Tested: Leakage to the outside - CFM25	22	11.3%	182.9	7.09	124	288
aid2_1	1st Sys Tsted:Leakage to outside/Total Sys Flow	22	11.3%	0.216	0.01	0.144	0.289
AID5A	Duct area – Attic	82	44.2%	218.8	19.21	40	887
AID6A	Duct insulation R-value - Attic	83	44.7%	4.7	0.15	3.7	18.4
AID5C	Duct area - Unconditioned Basement	92	49.4%	208.5	18.42	50	900
AID6C	Duct insulation R-value - Unconditioned Basement	93	49.9%	4.4	0.13	0	7

Variable	Question and response	# of Sample New Houses	% of Population of New Houses	Estimate	Standard Error of Estimate	Minimum	Maximum
IG1	Number of refrigerators in conditioned space	186	100.0%	1.1	0.03	1	5
IG2	Number of freezers in conditioned space	182	97.9%	0.0	0.01	0	1
IG4	Number of meals per week	184	99.0%	9.3	0.35	1	28
IG6	Number of loads dried per week	185	99.5%	7.3	0.39	0	21
IG7	Dishwasher loads per week	181	97.0%	4.5	0.23	0	14
SVHVACEL	HVAC savings:electric (kWh)	186	100.0%	97.9	11.31	-187	703
SVHVACOI	HVAC savings:oil (therms)	87	45.1%	234.0	20.41	-294	751
SVHVACGA	HVAC savings:gas (therms)	92	50.6%	291.2	23.00	-34	918
SVHVACPR	HVAC savings:propane (therms)	7	4.3%	261.9	54.75	92	542
SVHVACTH	HVAC savings:oil,gas,propane (therms)	186	100.0%	264.2	17.70	-294	918
EMSHVCE	HVAC SOx savings:electric (Lbs/year)	186	100.0%	0.910	0.11	-1.739	6.538
EMNHVCE	HVAC NOx savings:electric (Lbs/year)	186	100.0%	0.254	0.03	-0.486	1.828
EMCHVCE	HVAC CO2 savings:electric (Lbs/year)	186	100.0%	145.3	16.78	-277.5	1043.3
EMSHVCT	HVAC SOx savings:oil,gas,propane (Lbs/year)	186	100.0%	3.3	0.48	-9.21	23.51
EMNHVCT	HVAC NOx savings:oil,gas,propane (Lbs/year)	186	100.0%	3.1	0.19	-3.9	9.99
EMCHVCT	HVAC CO2 savings:oil,gas,propane (Lbs/year)	186	100.0%	3543.7	219.74	-4956.5	12661.
USHVACEL	HVAC unit savings:electric (Wh/sq ft)	186	100.0%	38.3	3.50	-55.3	244.4
USHVACOI	HVAC unit savings:oil (kBTU/sq ft)	87	45.1%	9.3	0.62	-15.9	21.45
USHVACGA	HVAC unit savings:gas (kBTU/sq ft)	92	50.6%	10.9	0.45	-1.06	29.22
USHVACPR	HVAC unit savings:propane (kBTU/sq ft)	7	4.3%	10.4	1.72	5.11	17.28
USHVACTH	HVAC unit savings:ol,gs,prpn (kBTU/sq ft)	186	100.0%	10.2	0.42	-15.93	29.22
PRHVACEL	HVAC pre-period use:electric (kWh)	186	100.0%	1661.2	191.84	39	6764
PRHVACOI	HVAC pre-period use:oil (therms)	87	45.1%	1076.9	59.40	490	2675

Variable	Question and response	# of Sample New Houses	% of Population of New Houses	Estimate	Standard Error of Estimate	Minimum	Maximum
PRHVACGA	HVAC pre-period use:gas (therms)	92	50.6%	1158.9	69.32	2	2512
PRHVACPR	HVAC pre-period use:propane (therms)	7	4.3%	1022.5	98.88	616	1478
POHVACEL	HVAC post-period use:electric (kWh)	186	100.0%	1563.4	184.46	32	6465
POHVACOI	HVAC post-period use:oil (therms)	87	45.1%	842.8	46.84	308	2196
POHVACGA	HVAC post-period use:gas (therms)	92	50.6%	867.6	53.28	3	2110
POHVACPR	HVAC post-period use:propane (therms)	7	4.3%	760.6	57.80	524	1026
HTMXLOAD	Heating maximum load (BTU/hr)	186	100.0%	64769.4	2959.14	21097	179742
HTCAP_MX	Heating capacity/maximum load	186	100.0%	1.9	0.07	0.66	5.13
CLMXLOAD	Cooling maximum load (BTU/hr)	108	57.9%	53477.5	2600.78	24197	109220
CLCAP_MX	Cooling capacity/maximum load	108	57.9%	1.1	0.02	0.82	2.01
AR2C	Refrigerator 1: Size - Ft3	178	95.9%	22.9	0.26	17	42
AR3C	Refrigerator 2: Size - Ft3	28	14.4%	17.4	1.31	3	27
AR4C	Refrigerator 3: Size - Ft3	4	1.9%	14.0	0.97	5	20
AAC2C	Room air conditioner 1: Size - Btuh	16	8.8%	6744.3	733.62	5000	12000
AAC3C	Room air conditioner 2: Size - Btuh	5	2.9%	8145.2	1564.73	5000	12000
TWS1B1	Indoor lighting, Compact Fluorescent Fixtures, Total Watts	1	0.4%	30.0	0.00	30	30
TWS1B2	Indoor lighting, Fluorescent Tube Fixtures, Total Watts	98	49.3%	156.4	15.60	0	1182
TWS1B3	Indoor lighting, Incandescent Fixtures, Total Watts	186	100.0%	2896.7	148.84	180	7880
TWS1B4	Indoor lighting, Halogen Fixtures, Total Watts	40	21.9%	486.8	136.10	50	5140
TWS1B5	Indoor lighting, High Pressure Sodium Fixtures, Total Watts	0	0.0%				
TWS1B6	Indoor lighting, Low Pressure Sodium Fixtures, Total Watts	0	0.0%				

Variable	Question and response	# of Sample New Houses	% of Population of New Houses	Estimate	Standard Error of Estimate	Minimum	Maximum
TWS1B7	Indoor lighting, Mercury Vapor Fixtures, Total Watts	0	0.0%				
TWS1B8	Indoor lighting, Metal Halide Fixtures, Total Watts	0	0.0%				
TWS2B1	Outdoor lighting, Compact Fluorescent Fixtures, Total Watts	3	1.4%	57.5	14.69	40	92
TWS2B2	Outdoor lighting, Fluorescent Tube Fixtures, Total Watts	7	3.6%	46.4	9.21	15	75
TWS2B3	Outdoor lighting, Incandescent Fixtures, Total Watts	184	99.0%	681.8	27.91	60	2400
TWS2B4	Outdoor lighting, Halogen Fixtures, Total Watts	36	18.6%	372.6	32.81	65	1300
TWS2B5	Outdoor lighting, High Pressure Sodium Fixtures, Total Watts	3	1.3%	94.3	26.17	60	150
TWS2B6	Outdoor lighting, Low Pressure Sodium Fixtures, Total Watts	0	0.0%				
TWS2B7	Outdoor lighting, Mercury Vapor Fixtures, Total Watts	0	0.0%				
TWS2B8	Outoor lighting, Metal Halide Fixtures, Total Watts	0	0.0%				
TWS1E1	Indoor lighting, On/Off, Total Watts	186	100.0%	2856.1	151.30	200	8042
TWS1E2	Indoor lighting, Dimmer/Rheostat, Total Watts	50	26.6%	789.5	87.52	60	5200
TWS1E3	Indoor lighting, Motion Sensor, Total Watts	12	9.4%	76.7	9.42	25	162
TWS1E4	Indoor lighting, Photo-cell, Total Watts	0	0.0%				
TWS1E5	Indoor lighting, Combined motion & photo, Total Watts	0	0.0%				

Variable	Question and response	# of Sample New Houses	% of Population of New Houses	Estimate	Standard Error of Estimate	Minimum	Maximum
TWS1E6	Indoor lighting, Timer control, Total Watts	0	0.0%				
TWS2E1	Outdoor lighting, On/Off, Total Watts	184	99.0%	627.2	26.49	60	2400
TWS2E2	Outdoor lighting, Dimmer/Rheostat, Total Watts	31	15.7%	323.0	46.14	54	900
TWS2E3	Outdoor lighting, Motion Sensor, Total Watts	42	21.4%	283.6	26.09	0	1050
TWS2E4	Outdoor lighting, Photo-cell, Total Watts	1	0.5%	60.0	0.00	60	60
TWS2E5	Outdoor lighting, Combined motion & photo, Total Watts	2	1.0%	246.4	35.17	200	300
TWS2E6	Outdoor lighting, Timer control, Total Watts	4	2.6%	231.1	33.19	120	360
Categorical Variables							
GI13	Was builder or homeowner an Energy Star Home participant?: Yes	178	96.2%	0.4%	0.44%		
GI14	Did they receive any gas utility heating equipment rebate?: Yes	179	96.7%	2.8%	1.50%		
GI15	Is any HUD financing involved in the construction of this home?: Yes	166	90.7%	0.5%	0.55%		
BI1	One or two family home: One family	185	99.5%	96.7%	2.23%		
BI1	One or two family home: Two family	185	99.5%	3.3%	2.23%		
BI5	Floors On or Above Grade: One	186	100.0%	12.7%	2.73%		
BI5	Floors On or Above Grade: Two	186	100.0%	83.4%	2.91%		
BI5	Floors On or Above Grade: Three	186	100.0%	3.1%	1.93%		
BI5	Floors On or Above Grade: Four	186	100.0%	0.5%	0.49%		
BI5	Floors On or Above Grade: Five	186	100.0%	0.0%	0.00%		
Bi6	Foundation Type: Slab on Grade	186	100.0%	2.0%	1.27%		
Bi6	Foundation Type: Vented Crawl	186	100.0%	0.0%	0.00%		

Variable	Question and response	# of Sample New Houses	% of Population of New Houses	Estimate	Standard Error of Estimate	Minimum	Maximum
Bi6	Foundation Type: Unvented Crawl Space	186	100.0%	0.0%	0.00%		
Bi6	Foundation Type: Conditioned Basement	186	100.0%	7.0%	1.92%		
Bi6	Foundation Type: Unconditioned Basement	186	100.0%	86.2%	2.61%		
Bi6	Foundation Type: More than one type	186	100.0%	4.7%	1.68%		
Bi7	Basement Actively Heated : Yes	186	100.0%	10.9%	2.08%		
Bi8	Basement Actively Cooled: Yes	186	100.0%	5.9%	1.78%		
EC1	Method of Compliance: J5.0 Prescriptive Practice / Default Package	186	100.0%	2.0%	1.24%		
EC1	Method of Compliance: J6.0 Component Performance / Manual Trade-Off	186	100.0%	0.0%	0.00%		
EC1	Method of Compliance: J7.0 MAScheck software	186	100.0%	66.6%	5.81%		
EC1	Method of Compliance: J8.0 Systems Approach / Total Energy Analysis	186	100.0%	0.5%	0.49%		
EC1	Method of Compliance: J9.0 Renewable Energy Resources	186	100.0%	0.0%	0.00%		
EC1	Method of Compliance: Method could not be determined	186	100.0%	30.9%	5.67%		
EC2	Compliance Method documentation provided to support compliance determination?: Yes	186	100.0%	68.6%	5.76%		
EC2	Compliance Method documentation provided to support compliance determination?: No	186	100.0%	30.6%	5.63%		
EC3	Building plans contain required energy code information?: Yes	186	100.0%	2.3%	1.57%		

Variable	Question and response	# of Sample New Houses	% of Population of New Houses	Estimate	Standard Error of Estimate	Minimum	Maximum
EC3	Building plans contain required energy code information?: No	186	100.0%	96.4%	1.81%		
MS81	Heating Plant Type: Boiler	186	100.0%	55.7%	6.05%		
MS81	Heating Plant Type: Furnace	186	100.0%	44.3%	6.05%		
MS81	Heating Plant Type: Heat Pump	186	100.0%	0.0%	0.00%		
MS93	: Pass	186	100.0%	46.4%	3.48%		
MS93	: Fail	186	100.0%	53.6%	3.48%		
MS94A	Do observed, on site values differ by more than 10% from the values in the compliance report for: Areas/Perimeters: Yes	132	70.5%	77.5%	3.57%		
MS94B	Do observed, on site values differ by more than 10% from the values in the compliance report for: Insulation levels: Yes	131	70.1%	32.5%	4.68%		
MS94C	Do observed, on site values differ by more than 10% from the values in the compliance report for: Glazing/Door U-Values: Yes	128	68.7%	44.0%	3.56%		
MS95	Does observed, on site value differ by more than 5% from the value in the compliance report for AFUE?: Yes	106	56.1%	22.7%	4.94%		
AEC1	Air infiltration mitigation measures are properly installed?: Yes	181	97.7%	16.5%	3.42%		
AEC2	Duct Systems are adequately sealed?: Yes	120	64.6%	19.2%	3.72%		
AEC3	Duct systems outside conditioned spaces are fully insulated?: Yes	123	66.6%	76.2%	6.46%		

Variable	Question and response	# of Sample New Houses	% of Population of New Houses	Estimate	Standard Error of Estimate	Minimum	Maximum
AEC4	HVAC hot water pipes fully insulated?: Yes	99	54.5%	71.8%	6.58%		
AEC5	Each HVAC system has its own thermostat?: Yes	184	99.1%	98.6%	0.78%		
AEC6	Each HVAC zone/floor has a readily accessible manual or automatic means to partially restrict or shut off the input to each zone or floor?: Yes	182	98.1%	88.8%	2.43%		
AEC7	Vapor retarder present?: Yes	185	99.5%	68.9%	4.55%		
EW4A	Frame type: Metal	186	100.0%	0.0%	0.00%		
EW4A	Frame type: Metal with break	186	100.0%	0.0%	0.00%		
EW4A	Frame type: Wood	186	100.0%	40.8%	4.72%		
EW4A	Frame type: Vinyl	186	100.0%	59.2%	4.72%		
EW4A	Frame type: Fiberglass	186	100.0%	0.0%	0.00%		
EW5A	Glazing type: Single	186	100.0%	0.6%	0.64%		
EW5A	Glazing type: Single with storm	186	100.0%	1.6%	1.60%		
EW5A	Glazing type: Double	186	100.0%	14.4%	3.93%		
EW5A	Glazing type: Triple	186	100.0%	0.0%	0.00%		
EW5A	Glazing type: Double with Low-E	186	100.0%	75.3%	4.24%		
EW5A	Glazing type: Double with Low-E and Argon	186	100.0%	8.1%	1.91%		
EW5A	Glazing type: Heat Mirror 88	186	100.0%	0.0%	0.00%		
EW5A	Glazing type: Double HM88 with Krypton	186	100.0%	0.0%	0.00%		
EW5A	Glazing type: Double Low E with Krypton	186	100.0%	0.0%	0.00%		
EW5A	Glazing type: Triple with Low E	186	100.0%	0.0%	0.00%		
EW5A	Glazing type: Triple Low E with Argon	186	100.0%	0.0%	0.00%		
EW5A	Glazing type: Triple Low E with Krypton	186	100.0%	0.0%	0.00%		
EW5A	Glazing type: Other	186	100.0%	0.0%	0.00%		

Variable	Question and response	# of Sample New Houses	% of Population of New Houses	Estimate	Standard Error of Estimate	Minimum	Maximum
EW6A	Operable or Fixed?: Operable	186	100.0%	97.4%	1.00%		
EW6A	Operable of Fixed?: Fixed	186	100.0%	2.6%	1.00%		
EW8A	U-Value type: Confirmed	186	100.0%	3.9%	1.26%		
EW8A	U-Value type: Default	186	100.0%	96.1%	1.26%		
ED4A	Door type: Steel with Insulated Core	186	100.0%	94.2%	2.06%		
ED4A	Door type: Wood w/ 7/16" panels	186	100.0%	0.0%	0.00%		
ED4A	Door type: Wood hollow core	186	100.0%	0.5%	0.49%		
ED4A	Door type: Wood solid core	186	100.0%	0.4%	0.42%		
ED4A	Door type: Wood w/ 1 1/8" panels	186	100.0%	4.9%	1.86%		
ED5A	Storm door type: Wood	185	99.5%	0.5%	0.48%		
ED5A	Storm door type: Metal	185	99.5%	20.0%	3.23%		
ED5A	Storm door type: None	185	99.5%	79.5%	3.20%		
ED7A	U-Value: Confirmed	186	100.0%	0.5%	0.49%		
ED7A	U-Value: Default	186	100.0%	99.5%	0.49%		
HVH1	Number of central systems in home: Zero	186	100.0%	0.0%	0.00%		
HVH1	Number of central systems in home: One	186	100.0%	84.1%	3.78%		
HVH1	Number of central systems in home: Two	186	100.0%	14.4%	3.72%		
HVH1	Number of central systems in home: Three or more	186	100.0%	1.5%	0.84%		
HVH2A	Fuel: Oil	186	100.0%	45.1%	6.02%		
HVH2A	Fuel: Gas	186	100.0%	50.6%	6.59%		
HVH2A	Fuel: Propane	186	100.0%	4.3%	2.16%		
HVH2A	Fuel: Electric	186	100.0%	0.0%	0.00%		
HVH2A	Fuel: Wood/Coal	186	100.0%	0.0%	0.00%		
HVH3A	System Type: Forced Warm Air	186	100.0%	43.6%	5.79%		
HVH3A	System Type: Forced Hot Water	186	100.0%	49.6%	5.62%		
HVH3A	System Type: Steam	186	100.0%	0.0%	0.00%		

Variable	Question and response	# of Sample New Houses	% of Population of New Houses	Estimate	Standard Error of Estimate	Minimum	Maximum
HVH3A	System Type: Electric Baseboard	186	100.0%	0.0%	0.00%		
HVH3A	System Type: Electric Radiant	186	100.0%	0.0%	0.00%		
HVH3A	System Type: Air to Air Heat Pump	186	100.0%	0.0%	0.00%		
HVH3A	System Type: Ground Source Heat Pump	186	100.0%	0.0%	0.00%		
HVH3A	System Type: Hydro Air	186	100.0%	6.8%	2.32%		
HVH8A	System location: Conditioned Space	186	100.0%	4.9%	1.50%		
HVH8A	System location: Unconditioned Space	186	100.0%	95.1%	1.50%		
HVC8	Whole house ventilation fan?: Yes	173	92.9%	4.2%	1.39%		
DHW2A	Fuel: Oil	186	100.0%	35.9%	6.01%		
DHW2A	Fuel: Gas	186	100.0%	52.6%	6.39%		
DHW2A	Fuel: Propane	186	100.0%	4.3%	2.12%		
DHW2A	Fuel: Electric	186	100.0%	7.2%	2.17%		
DHW2A	Fuel: Wood/Coal	186	100.0%	0.0%	0.00%		
DHW3A	Type: Conventional tank	186	100.0%	37.9%	3.99%		
DHW3A	Type: High efficiency tank	186	100.0%	20.0%	3.69%		
DHW3A	Type: Indirect fired	186	100.0%	22.4%	3.65%		
DHW3A	Type: Tankless coil	186	100.0%	19.8%	5.16%		
DHW3A	Type: Instantaneous	186	100.0%	0.0%	0.00%		
DHW3A	Type: Heat Pump	186	100.0%	0.0%	0.00%		
DHW5A	Tank location: Conditioned Space	186	100.0%	4.9%	1.50%		
DHW5A	Tank location: Unconditioned Space	186	100.0%	95.1%	1.50%		
AID7A	Duct insulation condition - Attic: Effective	83	44.7%	88.8%	4.32%		
AID7A	Duct insulation condition - Attic: Partially effective	83	44.7%	9.3%	4.17%		
AID7A	Duct insulation condition - Attic: Inadequate or missing	83	44.7%	1.9%	1.30%		
AID7C	Duct insulation condition - Unconditioned	92	49.5%	73.6%	5.92%		

Variable	Question and response	# of Sample New Houses	% of Population of New Houses	Estimate	Standard Error of Estimate	Minimum	Maximum
	Basement: Effective						
AID7C	Duct insulation condition - Unconditioned Basement: Partially effective	92	49.5%	19.9%	5.59%		
AID7C	Duct insulation condition - Unconditioned Basement: Inadequate or missing	92	49.5%	6.5%	2.33%		
IG3	Cooking fuel: Gas	185	99.5%	36.4%	5.44%		
IG3	Cooking fuel: Electric	185	99.5%	54.8%	4.33%		
IG3	Cooking fuel: Propane	185	99.5%	8.9%	2.44%		
IG3	Cooking fuel: Other	185	99.5%	0.0%	0.00%		
IG5	Dryer fuel: Gas	184	98.9%	24.6%	3.24%		
IG5	Dryer fuel: Electric	184	98.9%	73.0%	3.25%		
IG5	Dryer fuel: Propane	184	98.9%	2.4%	1.18%		
IG5	Dryer fuel: Other	184	98.9%	0.0%	0.00%		
AR1CAT	Number of refrigerators: Zero	186	100.0%	0.0%	0.00%		
AR1CAT	Number of refrigerators: One	186	100.0%	85.0%	3.26%		
AR1CAT	Number of refrigerators: Two	186	100.0%	13.1%	3.16%		
AR1CAT	Number of refrigerators: Three or More	186	100.0%	1.9%	1.07%		
AAC1CAT	Number of room air conditioners: Zero	185	99.2%	90.1%	2.28%		
AAC1CAT	Number of room air conditioners: One	185	99.2%	6.9%	2.05%		
AAC1CAT	Number of room air conditioners: Two	185	99.2%	3.0%	1.38%		
AAC1CAT	Number of room air conditioners: Three or More	185	99.2%	0.0%	0.00%		
AD1CAT	Number of dishwashers: Zero	186	100.0%	0.4%	0.40%		
AD1CAT	Number of dishwashers: One	186	100.0%	95.3%	2.06%		
AD1CAT	Number of dishwashers: Two	186	100.0%	4.3%	2.04%		
AD1CAT	Number of dishwashers: Three or More	186	100.0%	0.0%	0.00%		
ACW1CAT	Number of clothes washers: Zero	185	99.5%	1.1%	0.82%		

Variable	Question and response	# of Sample New Houses	% of Population of New Houses	Estimate	Standard Error of Estimate	Minimum	Maximum
ACW1CAT	Number of clothes washers: One	185	99.5%	97.6%	1.12%		
ACW1CAT	Number of clothes washers: Two	185	99.5%	1.3%	0.85%		
ACW1CAT	Number of clothes washers: Three or More	185	99.5%	0.0%	0.00%		
ACW2C	Clothes Washer 1: Type: Resource Efficient	175	94.8%	24.2%	3.48%		
ACW2C	Clothes Washer 1: Type: Standard	175	94.8%	75.8%	3.48%		
ACW2D	Clothes Washer 1: Vintage: New	179	96.5%	73.6%	3.48%		
ACW2D	Clothes Washer 1: Vintage: Used	179	96.5%	26.4%	3.48%		

C SEGMENTATION RESULTS

This appendix summarizes results from the segmentation analyses. The table on the following page presents several key variables for six different segmentations—climate, house purchase price, heating fuel, heating system type, the number of permits per building inspector, and whether the house passed or failed the code based on our MAS*check* analysis using the onsite survey data. The values shown in the table are the mean for all houses in the sample weighted to reflect the population.

Variable	MS82	MS91	MS92	ms92_91	HVH5A	AIV1	AIV2	MS93	AEC1	AEC2	AEC3	AEC4	AEC7
Description	AFUE	Max. UA calculated after onsite	Your Home UA calculated after onsite	MS92/MS91	System AFUE	Natural infiltration, air changes/hour	Measured infiltration, CFM50	Meet code	Infiltration measures installed	Duct systems sealed	Duct systems insulated	HVAC hot water pipes insulated	Vapor retarder present
Climate													
HDD < 6200	0.840	434.3	459.7	1.050	0.840	0.309	2251.0	49.4%	11.5%	17.1%	71.9%	74.9%	66.3%
HDD 6200 to 6400	0.861	470.6	477.4	1.007	0.858	0.350	2579.4	54.4%	18.7%	20.3%	79.6%	74.3%	73.5%
HDD > 6400	0.861	436.4	471.2	1.091	0.859	0.360	2515.3	34.9%	18.1%	19.2%	75.1%	64.7%	65.8%
Purchase Price													
$84,500 to $200,000	0.852	316.6	326.8	1.028	0.850	0.345	1737.5	49.4%	25.2%	6.1%	72.9%	75.3%	63.2%
$201,000 to $400,000	0.855	428.0	450.5	1.055	0.854	0.338	2396.9	45.9%	14.7%	20.1%	79.3%	71.2%	59.8%
$401,000 to $933,000	0.860	587.0	623.6	1.060	0.857	0.329	3202.4	39.5%	8.7%	22.5%	79.3%	73.6%	83.0%
Heating Fuel													
Oil	0.828	407.0	422.3	1.035	0.827	0.352	2419.6	36.2%	21.1%	25.2%	76.3%	71.0%	73.5%
Gas	0.875	486.5	516.2	1.063	0.873	0.331	2517.1	54.9%	13.0%	16.0%	77.7%	72.3%	63.9%
Propane	0.892	438.6	431.8	0.994	0.892	0.356	2296.6	53.2%	11.2%	17.7%	53.5%	79.1%	79.1%
Heating System													
Forced Warm Air	0.886	500.2	500.6	1.007	0.883	0.338	2542.9	64.0%	12.5%	16.4%	77.1%		73.2%
Forced Hot Water	0.831	391.9	424.8	1.073	0.831	0.347	2297.1	33.5%	21.4%	31.5%	82.9%	73.9%	62.8%
Hydro Air	0.827	530.8	605.6	1.126	0.826	0.330	3152.3	27.3%	7.2%	10.0%	54.9%	56.6%	84.6%
Permits per Building Inspector													
5 to 21	0.852	443.7	463.2	1.040	0.847	0.327	2342.0	51.1%	9.2%	21.8%	83.2%	70.1%	71.7%
29 to 64	0.852	430.8	456.0	1.062	0.852	0.341	2426.4	43.9%	21.9%	20.0%	69.0%	70.4%	61.1%
91 to 171	0.866	495.6	513.2	1.032	0.866	0.371	2765.0	43.2%	18.4%	12.9%	75.9%	80.2%	80.1%
Code compliance													
Pass	0.877	474.5	440.4	0.929	0.874	0.332	2463.8	100.0%	19.1%	19.5%	80.3%	73.0%	71.1%
Fail	0.835	426.2	496.0	1.150	0.835	0.350	2464.2	0.0%	14.2%	18.7%	71.7%	71.1%	66.9%

D MARKET ACTOR SURVEY RESULTS

The market player interviews were designed to provide the BBRS with qualitative assessments about the implementation of the 1998 amendments to the Residential New Construction Building Code. The study collected qualitative data from five sets of market players. Broadly speaking, these qualitative data, obtained primarily from in-person, open-ended interviews were intended to provide the BBRS with an understanding of the following functional and perceptual issues involved in implementing and enforcing the code:

- how the code changes were perceived by people who must work with them daily;
- how well the higher energy-efficiency standards and increased emphasis on energy efficiency are being integrated within the various aspects of the residential new construction market; and
- what actions might be taken by the BBRS to address problems and other concerns that would enhance the energy code's effectiveness within the scope of the housing market's present operations.

The XENERGY team operationalized these broad issues into research questions that provided the basis for interview protocols for each market player group (see the end of this appendix) developed in conjunction with the BBRS. The research questions included the following:

1) How, and to what extent, are **local code officials** monitoring and enforcing the energy code requirements? Are there aspects of the code that are enforced to greater or lesser degrees? To what extent does monitoring and enforcement vary among localities? How educated about the code are local officials? Do local code officials use MAS*check* interactively with designers and builders? Do they find value in using MAS*check* as a tool for documentation and enforcement? Is there a need for additional training or educational materials?

2) How do **designers and large and small builders** view the energy code? Are they aware of the major provisions? Do they see the different code compliance approaches as a benefit in providing them with greater design flexibility? Do they regard compliance as a barrier to completing their projects on time and on budget? Do they find enforcement to be similar across jurisdictions? Does the pattern of enforcement affect decisions to pursue projects in specific localities? What could the BBRS or other parties do to assist in better use of the current code's compliance tools?

3) What **designer, builder, and supplier** practices have altered since the implementation of the code? Are these changes improvements? If they have experience in other states that have adopted CABO MEC 95, how do they compare that with implementation in Massachusetts? What would they change?

4) How have **all parties** adapted to requirements concerning use of NFRC-certified windows? Are the MAS*check* provisions for custom windows adequate? Do prescriptive

window paths meet a real need? Has the new code affected perceived designer or customer demand for more energy-efficient windows? Are window manufacturers and supply houses providing adequate choice of conforming NFRC labeled products?

5) To what extent have building **design, development, and construction players** adopted MAS*check* as a preferred or commonly used tool? What features of MAS*check* are particularly useful or valuable? What barriers are there within the software package or its application that inhibit its wider use? What changes might be made to widen its adoption and/or increase its effectiveness?

6) How important are the existing **prescriptive packages**? Do they cover enough 'typical' construction situations to be broadly applicable? Are the different types of players (designers, builders, suppliers) satisfied with the prescriptive solutions? For those who have experience with MAS*check* and prescriptive packages what are the strengths and weaknesses of each?

7) What could be done to foster proactive attitudes toward enforcement of the energy code and use of the software tools to increase greater energy efficiency in new residential construction?

D.1 APPROACH

This subsection describes the approach used to conduct the market player interviews. First, it defines the market player groups interviewed. Next, it presents the approach used to allocate interviews among the groups and our sampling strategy.

D.1.1 Market Player Definitions

The BBRS identified five types of market players whose attitudes, understanding, and actions concerning energy code implementation were to be researched. These players included:

- local and state building code officials
- designers
- developers (build approximately 25 homes or more per year in Massachusetts)
- builders (build approximately 2-25 homes per year in Massachusetts)
- suppliers.

Local Building Code Officials

Local building code officials are responsible for all building code enforcement activities within the state. As part of the state's public safety network, they review and approve building permit applications for new residential and commercial construction as well as applications for additions and renovations. In many communities these officials are also responsible for zoning issues, and sometimes for planning issues and related health and safety concerns. The staff and resources accorded to local enforcement departments is a local decision and, accordingly, local code enforcement departments vary from a single individual (possibly part-time) to full-scale departments with substantial budgets, large staffs, and a variety of skill sets related to buildings available on call.

Since building permit applications are filed within each town, effective implementation of the energy code requires that local code officials be well informed about the code and that they enforce it knowledgeably and consistently. One BBRS goal is that the code is enforced evenly among towns as well as within them. To help achieve its goals, the BBRS offered training to all local officials in the State through a series of workshops prior to the implementation of the new code. Of 750 local code officials in the state, 621 participated in training.

District State Building Officials

The Massachusetts Department of Public Safety, which (along with the BBRS) is a part of the Executive Office of Public Safety, employs 14 state building officials in six regions who are responsible for the dissemination of knowledge and policies around the State. District building officials are organized on a regional basis, providing service to all regions of the State. Their primary function is to serve as state building code officials of record for any state-owned buildings – hospitals, universities, departmental facilities, and so on. They provide training to local code officials on a variety of building code related issues, including the residential energy code. They assist informally in local code interpretation and dispute resolution. The state officials are of interest to this study because they see the implementation of codes across regions and, as a group, have a geographically broader view of implementation issues.

Designers

Designers interviewed were primarily architects, but they also include state-licensed professionals who work for design-build companies or as independent consultants. Designers have the key role of developing home designs that conform to the energy code requirements, and providing detailed specifications for local officials to review and homebuilders to translate into materials purchases.

Builders

For the purposes of this study, we defined “builders” as companies that build from 2-25 homes per year in Massachusetts. Although there is little formal data on the characteristics of the home building industry in Massachusetts, the Homebuilders Association of Massachusetts estimates that 70 per cent of new home construction in the state is attributable to small builders.

The home builders we interviewed were either “spec” builders or “custom” builders. Spec builders generally build a small number of homes at a time from standard plans or plans they have developed on their own, and sell the homes with minimal buyer choice in modifications or options, often limited to choices in trim items, appliances, flooring, and so on.

Custom builders are more likely to be involved in home design, and to work with the buyer from an early stage in the design and construction process. Custom homes tend to be larger, more expensive, and have more options than spec homes.

Developers

For the purposes of this study, we initially defined developers as builders of more than 50 residential units a year within Massachusetts. However, we found that there were too few builders meeting that criterion within the state to provide a sufficient sample. Consequently, for the purposes of the study we dropped the threshold to approximately 25 new homes per year. Developers are important in this review because the options they offer (and limitations on changes to standard design specifications) control the package of features made available to prospective customers. One national developer offers a catalog of features for each type of home the firm builds; features not carried in the catalog are not offered at all.

Suppliers

Suppliers primarily include general building materials suppliers encompassing local and regional companies as well as at least one national chain. In addition to general building suppliers we included some insulation suppliers within this group. Suppliers have a special role with regard to builders, especially in a market dominated by small builders. Suppliers provide the materials for new home construction and also provide advice to builders about specific materials and equipment, which is important to builders making selections for price and other reasons. Some suppliers also do entire home designs for their builder customers. Suppliers also played a special role in the run-up to implementing the energy code—suppliers hosted 60 pre-implementation code workshops.

A number of suppliers also provide the service of completing the MAS*check* analysis for their customers. This additional role is a critical one because MAS*check* printouts have become the primary compliance documentation under the implementation of the energy code. It is important to understand how third parties, which often provide the MAS*check* analysis as an unpaid customer service are doing that job.

D.1.2 Allocation of Interviews and Sampling Strategy

Within the overall goal of completing approximately 50 interviews, the XENERGY team, with input from the BBRS, developed sub-quotas for each type of market actor. The intent of the market actor interviews was to seek input particularly from those market actors most closely involved in the daily implementation of the code. Table D-1 shows the resulting allocation and the actual number of completed interviews in each category; the allocation reflects the study participants' belief that some types of market actors should receive added emphasis. We interviewed a total of 52 individual market actors, but counted the group of state inspectors as a single interview. This group was not part of the original proposal; we suggested including it to gain perspective on regions of the state that might have been otherwise excluded (see the discussion below).

Table D-1
Interview Allocations and Completions

Market Actor	Interview Goal	Number Completed
Builder	12	12
Developer	9	8
Designer	8	9
Supplier	8	9
Local Code Official	11	11
State Code Official	1 (group of 3 or 4)	1 (group of 3)
Total Interviews	**50**	**50**

Sample selection for the market player interviews was based on a cluster sample approach. Given the small number of interviews in each category and the qualitative nature of the interviews and desired data, simple random sampling was not efficient or necessary for these interviews. The sampling approaches for the different groups are discussed below.

Local Code Officials

Sampling for local code officials followed the cluster sampling used to select towns for on-site building data collection by seeking neighboring towns in the same climate zone. The following criteria were used to guide the selection of towns in which code officials were interviewed:

- high numbers of permits (using 1999 MISER permit data)
- distribution of towns by climate zones within the state
- proximity to towns selected for onsites (assuming similar conditions and building practices within a local area)
- exclusion of towns selected for onsites (local building code officials only).[1]

These criteria resulted in the selection of the towns shown in Table D-2 for local code official interviews.

[1] This exclusion was intended to avoid any appearance that the study's purpose was to evaluate the performance of specific code officials rather than understanding how the implementation was progressing as a whole.

Table D-2
Characteristics of Towns Selected for Code Official Interviews

Town	Permits	Percentage*	Rank
Belchertown	111	0.7%	30
Beverly	58	0.4%	98
Billerica	94	0.6%	38
Framingham	67	0.4%	69
Ipswich	69	0.4%	63
North Attleboro	105	0.7%	33
North Reading	65	0.4%	76
Northampton	64	0.4%	79
Norton	153	1.0%	15
Taunton	186	1.2%	9
Wareham	88	0.6%	43
Worcester	227	1.5%	6
Total	1287	8.3%	

*Percentage=percentage of total permits reported statewide in 1999

This selection focused on towns that were ranked relatively high with respect to the number of permits issued in the previous year. The selected towns were concentrated in the eastern half of the state, with the exceptions of Northampton and Belchertown. Although this distribution reflects the state's population distribution and areas of active residential construction and it includes all the climate zones, it excludes the western counties of the state entirely. The community in western Massachusetts ranked highest in building permits, Pittsfield, issued only 31 permits in 1999, about half the number of Beverly, the town ranked lowest on the list in Table D-2.

Since one objective of this study was to identify regional differences and we anticipated the western part of Massachusetts would differ from other parts of the state because it relates closely to New York state, we believed it was sensible to elicit information about market players in that region even though no towns there were on our list. Therefore, with the assistance of the BBRS, we arranged to hold a discussion group with state building code officials representing central and western regions of Massachusetts.

Sampling for Other Market Players

Overall, the sampling strategy for other market players was to obtain a range of perspectives on energy-code implementation issues from a variety of players in and around a specific set of communities. Once the communities for local code officials were set, we intended to select samples of the other market player types from the same or nearby communities. We used commercial businesses databases classified by Standard Industrial Code (SIC) and similar listings, such as the membership of the Boston Chapter of the American Institute of Architects, to assemble lists of potential interviewees. Telephone calls were then made to prospective interviewees to schedule the approximately one-hour-long in-person interviews, or to arrange a time in which an interview could be conducted by telephone if an in-person interview was not practical. In some cases, the interview was conducted during the initial phone contact to take advantage of an opportunity that might not be available on another occasion. The success of this strategy varied considerably by market player type.

We were successful in getting a close correspondence among the local code official towns and materials suppliers. Since most suppliers interviewed served a local area of several towns, we were successful in getting more than one perspective on the issues that affected a particular area.

We were somewhat successful in finding builders in the targeted areas. Most small builders we interviewed tended to operate within a limited number of towns within the state and, consequently, dealt with the same local code officials and suppliers on a regular basis. Finding suitable builders to interview was complicated considerably by the fact that the interviews took place in the prime building season—early July through early September. It was not uncommon for builders to return phone calls after 8:00 or 9:00 PM. Several interviews were scheduled before 7:00 AM, or well into the evening hours, to accommodate builder schedules.

The community-based sampling strategy was less successful with designers. The designers we interviewed tended to be much less local in their practices, having customers in a variety of locales, some of them within Massachusetts; but often designer's customers were located in other New England states or within other regions of the country. Consequently, the Massachusetts-specific experience of the designers interviewed was often fairly limited.

Developers we interviewed fell into two categories. Some developers operated exclusively within a small area of the state. Others were part of larger companies not headquartered in Massachusetts and were primarily project managers of ongoing projects. These project managers could comment on the conditions they encountered on specific projects, but did not always have much experience within the state in the time since the energy code was implemented.

We had a great deal of difficulty finding interview subjects among developers for another reason. Local developers, more so than small builders, tended to have concerns about providing their views on the energy code, in general, and local code enforcement, in particular. These concerns may have stemmed from worry about possible effects of providing candid opinions in the interviews on current or planned development projects, which are often sensitive within the communities in which they are located. Several potential candidates requested a prior copy of the interview protocol and then refused an interview outright or were not available for repeated phone calls.

Table D-3 provides summary information on the characteristics of single-family homes being designed and built or inspected by market players interviewed for this study.

Table D-3
Characteristics of Homes Associated with Interviewee Groups

Interviewee Group	# Homes Built/yr		Home Size in Square feet		Estimated price in thousands	
	Mean	Range	Mean	Range	Mean	Range
Towns*	105	60-250	2,870	1200-5000	$274	$150-$1mil +
Designers	6	2-15	3,200	2200-5000+	$370	$350-$1mil+
Developers	54	20-170	3,300	2500-4000+	$340	$250-$700
Builders	11	2-18	2,700	2000-5000+	$260	$175-$650
* Towns in which local building code officials were interviewed						

D.2 FINDINGS

Using the research questions presented earlier in this section, interview instruments were designed for each group and 50 interviews were completed. The findings from the interviews are organized into the following topics:

D.2.1 Sources of code information and role of training
D.2.2 Knowledge of energy efficiency and the energy code requirements
D.2.3 Code enforcement process
D.2.4 Evenness of enforcement;
D.2.5 MAS*check* and the design process;
D.2.6 Ease of using MAS*check*;
D.2.7 Importance of flexibility;
D.2.8 Windows;
D.2.9 Heating systems;
D.2.10 Changes in practices due to code changes;
D.2.11 Perceptions of homebuyer attitudes.
D.2.12 Effects of the code on housing costs

D.2.1 Sources of Code Information and Role of Training

Since the code is a principal governor of new construction activities throughout the building industry in Massachusetts, it is critically important for all players to be aware when changes take place and to be well informed what specific changes mean to the conduct of business. We found that all market players were well acquainted with the changes to the residential building code. The information channels through which market actors learned about the code changes varied somewhat by market actor group.

Local building code officials were informed of the changes principally through BBRS workshops, training sessions conducted by state building code officials, and regional building code officials association meetings. All but one of the 11 local building code officials interviewed was trained in the revised energy code and the use of MAS*check* in workshops conducted by the BBRS prior to the code implementation. Several also had participated in additional training put on by regional associations of local building code officials and had participated in informal training sessions conducted by state building code officials under the BBRS training mandate.[2]

The design professionals we interviewed gained their information principally through professional publications, other designers (in larger firms), and organizations such as the Boston chapter of the American Institute of Architects. Designers also mentioned local building code officials as an important information source on energy code implementation practices, particularly since they felt that implementation practices varied among communities.

Some builders attended the BBRS workshops, but also got primary information from local building code officials, other builders, and regional chapters of the homebuilders' association. Builders also rely on supplier advice in purchasing materials that conform to the energy code. One example mentioned was the question of whether to move from 2x4 framing to 2x6 framing in the milder areas of the state. Suppliers' advice about framing size was influential for at least two builders interviewed. Most suppliers believed they wield a great deal of influence with less sophisticated builders who are not concerned with theory, but only with code compliance.

Developers got their information from trade publications, designers, and, to a lesser extent, local code officials. Only one of the eight developers we spoke with had attended a BBRS workshop, but most were aware that some training had taken place.

Suppliers cited several sources of information about the energy code and conforming practices and products. Seven of the nine suppliers interviewed had participated in training, including serving as host sites for BBRS-sponsored training. A regional building materials supplies company that also does complete building designs and a national building materials company sponsor informal training for customers on a variety of construction topics, including insulation and windows, using their own staff. Suppliers receive regular flows of information and training from manufacturers and distributors. Some of this information comes in the form of updated specification sheets and product announcements; some from representatives promoting their particular products. Suppliers generally exhibited great familiarity with the practical concerns of builders adjusting to the energy code implementation.

Of 52 individual market players interviewed (including 3 state building code officials in a discussion group as one interview), 31 had participated in some formal training prior to the

[2] The lone exception, although experienced in construction and municipal code enforcement, had just returned to the field after several years in another occupation.

implementation of the code. Table D-4 shows how many of each group we interviewed had attended some formal training.

Table D-4
Number of Interviewees Who Attended Formal Training

Market Player	Number in Category Interviewed	Number Trained
Developers	8	1
Builders	12	6
Designers	9	4
Suppliers	9	7
Local Building Code Officials	11	10
State Building Code Officials	3	3
Total	**52**	**31**

As noted above, prior to the implementation of the code the BBRS put on a series of workshops designed to inform all sectors of the industry that changes were coming, to inform them what the changes would be, and to also instruct them in the use of prescriptive packages and the MAS*check* computer program, which is a basic part of compliance with the new code requirements. Table D-5 describes the types of sessions presented by the BBRS, the number of presentations, and the number of participants, totaling almost 7,500. The BBRS made use of building materials supplier companies, as well as regional associations of builders and building officials, as sponsors and hosts of many of the training sessions.

Table D-5
BBRS-Sponsored Training*

Session Type	Number of Sessions	Participants
Contracted all day sessions targeted to builders, architects, others**	3	69
Contracted 3-hour sessions**	28	811
BBRS staff sessions sponsored by suppliers, builder associations, etc.	60	3,967
BBRS staff 1-hour sessions on MAS*check*	16	405
BBRS brief outreach presentations at community events	30	2,209
Totals	***137***	***7,461***

*Source: BBRS

** Sessions provided by outside agent with funding from the US Department of Energy

Most local building code officials recalled the BBRS-sponsored training as effective and informative. There was some difference of opinion about the utility of a theoretical approach compared to a practical approach to the subject matter. Some respondents believed a more checklist-oriented approach would have provided more useful day-to-day guidance in enforcing the new requirements, but training was viewed as positive overall. There were several requests that BBRS initiate some refresher training for experienced staff, as well as provide another round of basic training for new local building code officials.

Among other individuals interviewed, the training also was recalled generally as being informative. However, the interviewees often did not recall many of the session details during interviews conducted several months after the training. A number recalled demonstrations of the MAS*check* software. Overall the feeling was that training was useful, and should be periodically updated to reflect additional changes that take place in the code or in new energy-efficient building practices. Builders were most concerned about training taking away time from on-going work. If given a choice, most would restrict training workshops to the winter months, although at least one builder pointed out that in southeastern Massachusetts, building does not stop in the winter.

One builder suggested that a useful service by the state to keep builders and designers up to date would be providing the opportunity to purchase the state building code on a searchable CD-ROM when builders renew their licenses. An annually–produced CD-ROM could feature a section on recent and expected code changes. The builder noted that, since not everyone holding a contractor's license might want the CD-ROM, the state could offer it as a renewal option, over and above the basic license fee. The interviewer raised this suggestion in a number of subsequent interviews and found a high level of interest among interviewees.

D.2.2 Knowledge of Energy Efficiency and the Energy Code Requirements

General Energy-Efficiency Knowledge

We asked each market player how they assessed the level of knowledge about general energy-efficiency issues among their peers and other market players. The purpose of this question was to understand how market players believed they needed to relate to each other in completing their respective responsibilities in the residential new construction process. The interviewer also assessed each respondent's level of energy-efficiency knowledge and practices throughout the course of the interviews, although we did not establish any level of classification in such a qualitative review.

Such rating of the knowledge and competence of others is always open to question, but there was a fair amount of consistency in the how members of market player groups rated the knowledge of members of other groups. Table D-6 summarizes how each market player group rated the knowledge of all groups of market players using a rating scale of excellent, very good, good, fair, and poor.

Table D-6
Assessments of Market Players' Energy-Efficiency Knowledge

Rater \ Rated	Designer	Developer	Builder	Supplier	Local Code Officials
Designer	Good to Excellent	Fair	Poor to Fair	Fair to Good	Fair to Good
Developer	Good to Excellent	Good	Poor to Fair	Good	Good to Excellent
Builder	Good	Good	Good to Very Good	Good to Excellent	Fair to Good
Supplier	Excellent	Good	Fair to Poor	Very Good	Good to Very Good
Local Code Officials	Good to Very Good	Fair to Good	Poor to Fair	Good	Good to Very Good

As the table indicates, most market players thought that others in their own line of work had high levels of knowledge about energy efficiency. Most respondents rated their own knowledge levels to be very high, even authoritative in some cases, and generally thought they personally were more informed than most of the other market players with whom they regularly interacted in the housing market. Builders received the lowest ratings from the other groups and designers received the highest. Most market players rated local building code officials' knowledge as good. Notwithstanding their high self-ratings, however, it was not uncommon among all player groups to express a desire for more information on energy efficiency, including advances in equipment and materials, and better practices, and to look to the BBRS as a good source of information, along with their respective professional associations.

Our assessment of respondent's knowledge of and interest in energy efficiency knowledge was that there was great variability in both the level of knowledge and interest among all groups. Designers and suppliers appeared to be most conversant with energy-efficiency principles and practices. Local building code officials and developers showed great variation in their levels of knowledge and interest. Among developers, levels of knowledge and interest appeared to be highest among project managers and others who have direct responsibilities for management and oversight of construction. Those with more marketing and "big picture" development responsibilities were less interested and knowledgeable and did not generally believe those concerns were all that relevant to their own responsibilities. The smallest builders tended to be the least concerned and least knowledgeable about energy efficiency. Most of these individuals have pursued their craft for many years and have "tried and true" ways of doing things that they do not like to change unless required to do so. This group tended also to have the least liking for MAS*check* and its flexibility, preferring prescriptive rules over having sets of choices to ensure compliance (although we did not find builders using the prescriptive options in their permit applications).

Energy Code Knowledge

We found that local building code officials and most other market players were consistently familiar with the requirements and changes required by the code in almost all areas. If there was any gap in knowledge, it was around the question of alternatives to using MAS*check* as the way to demonstrate code compliance. Several builders did not believe local building code officials would accept anything other than a MAS*check* printout with a new construction permit. At least two spec builders were not clearly aware that they could use a prescriptive submission. It was clear that local building code officials were considered to be authoritative sources within their respective towns and considered the last word in most questions of code interpretation, though additional mechanisms existed to resolve disputes.

A number of people in a variety of roles were unclear about what extent of renovation triggered the energy code requirements, and seemed to think this issue had not been clearly resolved at the local level. Since renovations were not part of the scope of this study, we noted this concern, but did not pursue the issue in depth.

D.2.3 Code Enforcement Process

General Code Enforcement and Energy Code Issues

Local building code officials uniformly regard themselves as being primarily responsible for public safety. With respect to residential new construction, their main concerns are the structural integrity of the homes being built in their communities, safety of gas and electricity installations, proper sewage, and similar safety concerns.

Local code officials have significant responsibilities in addition to residential new construction permit and inspection duties in most communities, and varying resources to meet them. Across the towns we contacted, these other responsibilities included zoning, commercial and industrial construction, building renovations of all types, historic preservation, weights and measures, "fence viewing,"[3] and miscellaneous other responsibilities.

Allocations of personnel and other resources to plan review and inspectional duties are entirely local decisions and do not necessarily reflect the level of construction activity within the towns. Three small communities that have had sustained annual production of more than 100 new homes per year had 1½ to 2 full-time positions devoted to all aspects of new construction. Some of these positions were actually individual inspectors who were contracted as needed to perform various duties, rather than full-time employees. Most local code officials reported little or no increases in resources over the past several years, even if construction activity had increased dramatically. Whether or not communities have adequately allocated their code enforcement resources toward residential new construction is an issue outside this study's scope.

We note that most local code officials interviewed viewed energy code implementation as additional work and responsibility on top of their basic duties and most local code officials

[3] "Fence viewing" is a traditional New England way of settling disputes on exactly where fences ought to be.

viewed enforcement of the energy code as a lesser priority than the basic public safety concerns. However, all stated that the code must be enforced and took it seriously.

The greatest part of the added workload associated with the energy code did not result from applications for new construction, but applications for additions and renovations, particularly those where the homeowner acted as general contractor. Homeowners were rarely conversant with building code issues in general. The energy code requirements added another layer of concerns and problems, even when prescriptive paths were used, which seemed to be the most common situation for homeowners. Local building code officials devote significant time to homeowner-renovators partly as a public safety issue and partly as a local government customer-service issue of helping residents get their additions completed.

MAScheck

On the subject of MAS*check*, a majority of local building code officials (7 of 11) was supportive of MAS*check*'s use. Three were enthusiastic about it for its flexibility. Three more expressed overall support for the continued use of MAS*check*. The remainder expressed varying degrees of support for a highly prescriptive system as an alternative to or replacement for MAS*check*. The local building code officials who favored a return to prescriptive standards argued that most builders built the same house over and over and the flexibility contained in MAS*check* made little difference to them. Three local building code officials and several builders and suppliers noted that some builders always insulated attics to the same R-value, even if MAS*check* would allow them to use less insulation, because they preferred consistency over flexibility. At the same time, we did not hear that those local building code officials who favored checklists generally tried to steer builders to the existing available prescriptive options, and it was not clear why this was so.

To simplify the enforcement process, we found that code officials in every town surveyed required each new home permit application to be accompanied by a MAS*check* printout that indicated that the home in question had a passing grade under the code requirements. Prescriptive package submissions, while accepted, were rare for new construction; most local code officials could not recall receiving one for a new home.

In 7 of the 11 towns surveyed, review of MAS*check* did not extend beyond checking that the printout was submitted and the proposed home design passed. As noted in the body of this report, this may be a limitation of relying on the MAS*check* approach without adequate code official awareness. In those towns that conducted any additional compliance MAS*check* activity, that activity was mainly limited to checking that the net window and wall areas corresponded between the plans and the MAS*check* printout. Two towns required a copy of the printout to be maintained onsite with an onsite copy of the plans.

Onsite Inspections

Onsite inspection practices were more difficult to assess through the interviews. Officials in most towns said they conducted from three to five inspections during the course of the average new home construction. If problems were found early, they might inspect more often. Foundations and framing were consistently checked, but sealing at contact points was often not routinely checked, or could not be checked because the work was already covered up by other construction when inspections occurred.

Responsibility for checking sealing of penetrations was not consistently assigned among towns. In some towns, that inspection duty was assigned to electrical and/or plumbing inspectors. In others, the local building code officials or their staff inspectors checked on sealing. Where other town departments or officials had this responsibility, local building code officials often could not comment on how often or whether penetration sealing was checked.

The presence of insulation was always checked, but the degree of checking varied. Some towns had a distinct insulation inspection and attempted to view all insulated areas of the envelope. In other towns, insulation was checked at a construction stage when some insulation might be covered or not readily accessible.

Three local building code inspectors (of 11 interviewed) mentioned duct sealing as an area of concern. One official, who thought ducts were sometimes not well sealed and insulated, said he could not always observe the entire duct system, mainly because of inspection scheduling problems. The onsite survey data confirmed that duct systems often were not sealed properly. No officials provided empirical data supporting this observation, however.

Code officials indicated that window inspections had not posed significant difficulty or problems in the recent past. During the initial phase of code implementation, there were some problems with NFRC-approval labels falling off or being removed before inspectors could see them. These problems were resolved, in large part, by builders routinely obtaining windows from major manufacturers that put out entire lines of NFRC-approved windows.

D.2.4 Evenness of Enforcement

The Residential New Construction Building Code is promulgated by the BBRS across the entire state and is applicable to all communities in the state. Enforcement of the code with respect to issuance of building permits, inspections, and final approvals, however, is a local responsibility. Local building code officials who have the primary enforcement responsibility vary greatly in their responsibilities, priorities, skill areas, levels of training, staff resources, and the time and budget available to devote to enforcing the energy-efficiency aspects of the code.

We found that all types of market players indicated that towns varied in the extent to which the energy code was enforced at the permit application and inspection stages, and the degree of emphasis on particular measures and installation techniques. This variability not only extended to the degree of review and inspection, but also included differing emphasis on particular aspects of the energy code.

Some local building code officials closely reviewed the MAS*check* printout and checked for correspondence of net wall and window values between MAS*check* and the building plans, but most local building code officials said they did not check for correspondence at all. In some towns, permit applications were required to have complete door and window schedules as part of the plan package, but this did not appear to be a common requirement.

With respect to energy-efficiency measures emphasized by code officials, there were also variations across towns. In some towns, for example, officials placed a great deal of emphasis on insulating and sealing foundations and inspected closely for proper techniques. Some local inspectors looked very closely at insulation of gable ends and continuous insulation layers over all surfaces. Some inspectors placed more emphasis than others on sealing and wrapping heating ducts. One builder commented that he could tell what sort of seminars had recently taken place because all the inspectors in his area would concentrate on the same measures for a while. He noted this phenomenon was not limited to energy-related issues, but applied to all aspects of new construction code enforcement.

Local building code officials agreed that these variations existed and attributed them to the variations in circumstances among town building departments, though they generally said they tried to enforce the code as uniformly as possible. Officials said that the state had been helpful with informal periodic training provided by regional state building code officials, but the frequency and content of this training also varied considerably among the regions. However, some local building code officials believed certain aspects of the code were more important than others and they enforced those requirements more closely.

There were several comments about the lack of ventilation standards in the code. The concern was that houses might be built too tight, thus increasing interior moisture levels, which could cause damage to the building structure. There were also health concerns about indoor air quality in excessively tight homes. Opinions on this issue were strongly divided, however. Some local building code officials stated that with current building practices there was plenty of air movement through the average new home and there was nothing to worry about.

Despite the variability of enforcement practices *among* towns, most designers, developers and builders agreed that enforcement was consistent *within* towns, and that local building code officials were effective at communicating what they were looking for in permit applications and on inspections. They also said the variability in enforcement of the energy code was comparable to variability among towns in enforcing other aspects of the code and generally took the variations they found in stride.

D.2.5 MAScheck and the Design Process

Because MAS*check* is a flexible tool in which several types of measures can be adjusted, we asked designers, builders, and local building code officials about the extent to which MAS*check* was used actively in the design process. Designers uniformly told us they ran MAS*check* to check for compliance after all their designs were essentially complete. They adjusted specifications if a building failed. Buildings failed MAS*check* most often where large areas of window glass were included, such as window walls facing scenic views. This problem appeared to occur most often in high-end custom-designed homes.[4] Despite these concerns, however, no

[4] Some designers believed that if MAS*check* factored solar gain into the calculations, more of these homes would pass, particularly because high-end designs tended to include substantial amounts of insulation in foundations as

designer said that complying with the code had forced any significant redesign in a recent project. Some designers did note the compliance as an added cost that they passed on to their customers as a design service, generally rolled into the design fee.

We spoke at length with suppliers about using MAS*check*. Of the nine suppliers we spoke with, including a national hardware/building supplies company, all but one had done MAS*check* runs for their customers. Suppliers do MAS*check* compliance runs as a customer service and do not charge for the service. Most suppliers reported that they were doing fewer MAS*check* runs for their customers than they were a year ago. They reported more builders were becoming comfortable with computers in general and with the MAS*check* software, in particular. Suppliers saw their role toward builders as a helping one, particularly if they were in a region of the state where the energy code was moving builders to more use of 2x6 framing than previous common practice. Suppliers were helpful to builders in structuring materials orders to efficiently comply with the code.

One MAS*check* issue that arose with both insulation suppliers and with general building materials suppliers was heating system efficiency. Several times we were told that suppliers doing MAS*check* runs for builders often did not know what efficiency heating system would be placed in the home. Sometimes the builder does not know until later in the process. When they do not know heating system efficiency, suppliers routinely used the minimum passing efficiency in the calculation. Doing this could increase insulation requirements for the building or require more efficient windows. As a result, builders who installed heating systems above the minimum efficiency but didn't have that factored into the MAS*check* run might be installing more insulation or higher efficiency windows than they really needed to achieve a passing score. Given the relatively low compliance rate, however, this did not appear to be the case.

Local building code officials said that they primarily checked for pass or fail values. None reported seeing a failing MAS*check* printout attached to a new construction permit application, although several noted that this had happened with renovations proposed by homeowners. Local building code officials believed that they had an obligation to work with homeowners trying to package improvements themselves, and most of the local building code officials we spoke with spend significant time at this task. Local building code officials did not expect to make any significant investment of their time to correct MAS*check* –related problems for new construction applications submitted by professionals.

D.2.6 Ease of Using MAScheck

We asked respondents of all types about the ease of using MAS*check*, the time involved, and possible expenses added by its use. Designers, builders, suppliers, and local building code officials who actually used MAS*check* generally found it straightforward to use. Time required to enter data decreased once users were familiar with the order and format of the data requested.

Designer estimations of the time required to run MAS*check* varied from an hour to a day, depending somewhat on the complexity of the design and whether they needed to make changes

well as walls and attics, advanced window glazing, efficient heating systems, and, increasingly, active ventilation systems.

for compliance purposes. Most of the designers we spoke to did the MAS*check* runs themselves, but two designers said they routinely left the MAS*check* runs to their general contractors and had rarely had to make more than minor changes to reach a passing value.

The only problem designers mentioned with MAS*check* was that the majority of those we interviewed routinely used Computer Aided Design (CAD) programs on computers with Macintosh operating systems, which are not compatible with MAS*check*. In most cases, designers do their MAS*check* runs on a Windows operating system computer after they have completed the major building design elements on their CAD programs. Two architects we interviewed had elected to do the paper and pencil version of MAS*check* because they didn't have computers with compatible operating systems readily accessible. This added some time and cost for them, but appeared to work satisfactorily. This situation suggested that designers would be benefit from a Macintosh operating system version of MAS*check* or a utility program to convert their files into a format compatible with MAS*check*, which might be more achievable.

Some suppliers who work with small builders said many of their small customers did not own computers or they used them in a very limited fashion. In some family-owned businesses, the builder often relied on another family member to handle the business operations such as taxes, billing, etc. The computer expertise was, therefore, separated from the building expertise. In these situations, dealing with MAS*check* could be a significant burden and suppliers could provide an important service. But as noted above, it appeared from supplier reports of decreased requests for this service that more small builders were doing MAS*check* runs themselves

Builders who were comfortable with using personal computers did not complain about the requirement to use MAS*check*, or find any significant problems in using it. Builders who did not routinely use computers in their business were more likely to describe MAS*check* as difficult to use, but there were no common complaints beyond those about the drudgery of data entry. Builders who did not use computers at all and relied on other parties to complete MAS*check* for them were the least likely to say anything favorable about the program.

D.2.7 Importance of Flexibility

One of the potential benefits of MAS*check* over prescriptive approaches is that designers and builders have some freedom to work with envelope and equipment specifications to ensure that a home meets the code requirements. They are not forced into building every home with exactly the same levels of insulation, percentage of glazing, and so on. This flexibility can allow custom designers to accommodate client desires, and allow designers and builders to take advantage of site or local climate characteristics to build homes that comply with the code that are not necessarily all the same. We asked developers, designers, and builders the extent to which they took advantage of this flexibility offered by the use of MAS*check*.

In general, there was praise for MAS*check*'s flexibility. Designers of custom homes liked the ability to balance components, though some said MAS*check* was not flexible enough. Some said that MAS*check* did not provide credit for solar exposures and winter heat gains in rooms with large glass areas and thermal mass. In the opinion of some, MAS*check* also did not easily accommodate advanced heating systems, although these designers said they had found local building code officials willing to work with them on atypical designs, especially in more expensive custom homes.

Despite designer and other market players' approval of MAS*check's* flexibility, several respondents questioned the extent to which that flexibility was needed. One national developer sells about six basic designs in each development, and has a wide-ranging catalog of options of materials, finishes, equipment, and appliances from which buyers can choose. The basic designs, however, rarely changed so MAS*check's* flexibility was not needed. The smallest builders we spoke with built two or three designs over and over with only cosmetic changes. These smaller builders usually built on spec—i.e., the basic design and most of the "features" were decided before a buyer came along—so the flexibility of MAS*check* was not utilized. Although larger builders might be expected to seek the flexibility allowed by MAS*check*, most built on a limited number of designs in a given year. Similarly, some of the custom builders noted that many of their homes were built for customers who provided designs purchased commercially, but the designs came from a relatively small number of design companies.

We also frequently heard the comment from suppliers and builders that builders preferred to insulate homes consistently, always putting the same insulation type, depth, and R-value in walls, floors, and ceilings. This consistency was important to builders because it simplified their ordering of insulation and framing materials. It also simplified the instruction and oversight of the workers who installed insulation. Builders told us they have a lot of worker turnover in an active employment market. They often have to hire people who have low skill levels and little experience. Telling their crews to do the same operations the same way each time is more cost-effective for them in the long run than occasionally saving money on materials where MAS*check* would pass a lower R-value.

Overall, most developers and builders reported that they built essentially the same few home types over and over with minor variations that rarely affected energy-code considerations. Certain styles predominate for a few years and then others become popular with homebuyers and builders. Several builders, therefore, saw a prescriptive approach as more suited to the bulk of their work, but most would also like to have the options available with MAS*check* for the homes that did not fit their usual designs.

D.2.8 Windows

There was general agreement that the implementation of residential new construction code requirements to use only windows that were certified as meeting requirements of the National Fenestration Rating Council (NFRC) has worked well.

Designers have been able to specify windows that fit within their overall designs in almost all cases. Designs produced for mass production with small amounts of customization for individual tastes were not at all affected. The only "problems" mentioned were in some high-end custom homes where unusual window shapes were sometimes constrained by the code requirements.

Developers and builders for the most part were supportive of applying the NFRC requirements. One small custom builder said the window requirements served to level the field among builders by moving the level up for everyone. Previously, builders and developers could advertise they provided “energy-efficient” windows, but did not have to demonstrate any proof of that claim—in the past, some builders sold “energy-efficient” windows, which really were inexpensive, poor performers, at a premium price to homeowners who had no performance yardstick against which claims could be measured. Builders who used truly more efficient windows were sometimes penalized in very competitive markets before the NFRC certification requirement came into effect.

The only dissent to the window requirements came from a spec builder who believed all the energy code requirements served only to increase the price of homes and keep more people out of the market.

D.2.9 Heating Systems

Two questions about heating systems were of special interest in this study. First, what was the effect of the code changes on the efficiency of heating systems being installed? Second, what was the effect of the code on sizing heating systems, given that homes built under the new code should have lower heating loads as a result of increased shell efficiencies?

Heating System Efficiencies

The revised code set minimum heating system efficiencies for furnaces and boilers, depending upon the heating fuel. Table D-7 below shows the minimum required efficiencies for each fuel and heating system type:

Table D-7
Minimum Heating System Efficiencies,
by System and Fuel Type

(Source: 780 CMR Appendix J)

System Type	Fuel	
	Gas	Oil
Furnace (<225,000 Btu/h)	78%	78%
Boiler (<300,000 Btu/h)	80%	80%

Heating systems complying with the minimal efficiencies were readily available in all areas of the state in which we conducted interviews, but so were more efficient conventional systems (systems that did not require special air intakes or venting). More efficient systems were often obtainable by builders at little or no incremental cost over the price of the minimum efficiency units, and many builders said they routinely bought more efficient systems because those were the ones available from suppliers. Some custom-home designers and custom builders have adopted a greater use of sealed combustion higher efficiency units, but the most common practice is to leave the specification of particular heating systems to the plumbing or HVAC supplier for the project.

With regard to code enforcement, there appeared to be spotty checking on heating system efficiencies. Most local building code officials checked for compliance with the minimum efficiencies on the MAS*check* printout. Only a few said they checked nameplate ratings on site. Determining the degree of enforcement in this area was difficult because it was common in many towns for heating systems to be checked by a plumbing inspector, not the building inspector. Plumbing inspections appeared to concentrate on safety issues; there was no special emphasis on energy efficiency among the towns we contacted. There was little or no checking back between the rated efficiency of the unit installed and the efficiency specified on the permit. However, if the self-reported practices of builders installing high-efficiency units are correct, it seems likely that discrepancies between specified and installed units would favor more efficient units. The onsite survey data, however, did not provide significant evidence of this.

Heating System Sizing

The code requires heating system sizing to be governed by the requirements of the Air Conditioning Contractors Association's Manual "J" (or equivalent procedure)[5]; this requirement should lead to the installation of lower capacity equipment in homes that have lower heating loads as a result of making the building tighter and more energy efficient. We found very little indication, however, that sizing practices have changed with the implementation of the revised code.

Heating and plumbing contractors are key to this process. Most designers, developers, and builders said they relied on plumbing contractors, assumed those contractors abided by the code requirements, and did not know themselves what actual sizing practice was (and had not inquired about it). Additionally, several builders said they preferred to oversize units, by values ranging from 25 to 50% above the requirements calculated for their buildings.[6] Reasons stated for this practice included these:

- Buyers are less likely to complain that the unit could not provide enough heat in cold weather.
- Homeowners are likely to build onto their homes, and larger units will be able to meet the future increased loads.
- Oversized units don't work as hard and are likely to last longer than those sized just right.

[5] 780 CMR Appendix J, based upon the Council of American Building Officials Model Energy Code 1995 Edition
[6] Note that the code permits oversizing up to 25% above the design load requirements.

Builders who routinely oversized said that the impact of using larger heating systems on housing cost was too small to matter. They also said that homebuyers rarely inquired about efficiency and never inquired about sizing.

Although we did not ask the same questions regarding cooling equipment, past studies have suggested that similar practices probably applied to the sizing of cooling equipment as well.

D.2.10 Changes in Practices Due to Code Changes

Overall, market players reported few changes in design or construction practices resulting from the implementation of the energy code beyond windows. The NFRC window certification requirement was a strong exception that has forced a substantial, mandated change. Although there appeared to be much more attention paid to insulating and sealing foundations than previously, some builders said that they had been moving in that direction for some time and the new rules had not required them to make many changes.[7]

The situation with insulation and framing was a little more complex and more climate-dependent. In the colder, middle and western parts of the state, market players reported that homebuyers and local building code officials had been more attuned to energy concerns for some years. Use of 2x6 framing was common in some parts of the state before the changes to the code. With the implementation of the energy code there was increased use of 2x6 framing in most parts of the state, with the general exception of southeastern Massachusetts. With fewer heating degree-days in an average year than other parts of the state, moving to 2x6 framing appeared to be optional, and it was not clear from interviews how widespread it was. Similarly, we found some reporting of increased use of 2x10 framing in attics to accommodate increased insulation. One insulation supplier serving mainly southeastern Massachusetts reported that builders were often reluctant to move to 2x10's and were installing fiberglass insulation with their standard framing and accepting some compression. This supplier did not believe there was serious loss of R-value from this practice and it was accepted in some towns.

Heating system efficiencies, while rising, may be driven by a market that is producing higher efficiency units at little or no incremental cost above the cost of minimum efficiency units. Some specific investigation of this market would be helpful to understand what forces are currently driving it.

[7] We note that some local building code officials, designers, and builders expressed concern about possible homeowner safety problems if homes built under the new code don't have adequate makeup air because of greatly decreased infiltration into basements resulting from greater efforts to seal them. Ventilation requirements in living areas were not addressed in the recent code changes, but several respondents believed that they should be for this reason and to prevent buildup of excess moisture within the building envelope.

Designers and custom builders reported increased interest in and use of rigid insulation, principally to accommodate cathedral ceilings. There was also a growing use of in-floor radiant heating systems and installation of two heating systems in larger homes.[8]

D.2.11 Perceptions of Homebuyer Attitudes

During the period when these interviews were conducted (July through early September 2000), there were frequent news stories suggesting that fuel prices would rise in the coming fall and winter. Nevertheless, there were widely shared beliefs on the part of all types of market players we interviewed that energy efficiency was not an important item in the minds of new home buyers. The exception to this attitude was in western Massachusetts, where a colder climate prevails and there is perhaps a greater awareness of energy issues in general than in other parts of the state. Builders, designers, suppliers, and local building code officials from western Massachusetts all seemed to place a somewhat higher value on energy efficiency than their counterparts to the east. In this region it seemed that building energy-efficient homes was a more common practice than elsewhere. However, even in this area it did not appear that there was much marketing of energy efficiency as a feature of new homes.

Developers and builders generally did not report much value to marketing energy efficiency in the current highly competitive and expanding market. They said that what sells prospective buyers were the following, in approximate order of importance:

- square footage (living space)
- high ceilings
- large window areas
- open floor plans
- well equipped kitchens
- multiple bathrooms
- playrooms

Most of the market was described as looking for comfort and convenience. Every developer and builder was quick to say that buyers were very conscious of value and price, but energy efficiency was not part of the picture for most buyers. Buyers of high-end custom homes (over $1 million) expected homes to be energy efficient and tended to value efficiency more than other buyers, but the energy efficiency itself still not did appear to be a selling point.

Those buyers for whom cost is a pressing concern make many choices in selecting features and appliances and there are always cost consequences. One developer described the cost-benefit of increased energy efficiency this way:

> "My typical customer will never realize the benefits of the increased costs to make a home more efficient at the outset. They will live in one of my homes 5-7 years and then

[8] A second heating system is said to save on duct runs in larger homes, providing more reliable comfort.

> sell. There's no payback for them. They get better value from a finished playroom–that translates into a more desirable house and a better price when they're ready to sell."

The one exception to this developer viewpoint was a developer who is now participating in the Energy Star New Homes program. That developer believed that Energy Star was a sufficiently recognized label to attract customers to his homes.

Since these interviews took place there have been a number of developments that have greatly increased coverage of energy issues in the press and television. Electricity prices have begun to rise, partially as a result of planned events in restructuring the electric utility industry in the state, and partly because of increased fuel prices. Home heating oil prices rose dramatically for a time, and then returned to more typical seasonal levels. Natural gas, which is the fuel of choice in most new construction, is experiencing major price increases as transport companies pass through higher wholesale market prices to customers. These events may change the equation for homebuyers if they persist. During the interview period, however, we did not observe any evidence that such a change had happened or was likely to occur.

D.2.12 Effects of the Energy Code on Housing Costs

We asked market players about the effects of the code on housing costs. Most respondents found this a difficult question to answer but, on reflection, placed the additional costs in the range of $1,000-$3,000 per home, with the greatest increases coming from upgraded windows, insulation, and framing. Considering that the typical home being built by most builders was priced between $250,000-$350,000, this seems like a modest increase, but the estimate should be regarded as very soft.

D.3 CONCLUSIONS AND RECOMMENDATIONS

This section presents conclusions and recommendations for action on the part of the BBRS with respect to optimizing the implementation of the Residential New Construction building code, following the seven operational questions in the evaluation proposal. The conclusions presented rely upon the observations and findings in subsection D.2 above.

1. How, and to what extent, are local code officials monitoring and enforcing the energy code requirements? Are there aspects of the code that are enforced to greater or lesser degrees? To what extent does monitoring and enforcement vary among localities? How educated about the code are local officials? Do local code officials use MAScheck interactively with designers and builders? Do they find value in using MAScheck as a tool for documentation and enforcement? Is there a need for additional training or educational materials?

Local building code officials are clearly enforcing the energy code among the communities we contacted, but they do so as public officials whose highest priorities are the public safety aspects of the code. They expressed concern about structural integrity of new homes, safe installations of electrical and combustion appliances, environmental issues such as design and installation of sewage, and similar safety concerns. Some officials expressed concerns about energy-related aspects of homes, such as adequate air for combustion appliances, moisture transport around insulated spaces, and, in a very few cases, proper ventilation and indoor air quality in living spaces.

Though most local building code officials expressed support for the energy code changes, they gave enforcement of those sections of the residential building code lower priority than safety related issues throughout the application and inspection processes. In the towns we visited, submission of a MAS*check* printout showing a passing score was a required part of the application process for a new home construction permit, but in most towns that was about the end of the process. Comparing MAS*check* inputs and building plan specifications for net window and wall areas was uncommon. Checking the MAS*check* against new homes as they were being constructed was very rare. MAS*check* had an important role as a primary piece of documentation, but the lack of follow-up in many communities could encourage permit applicants to "adjust" specifications on plans that might otherwise fail.

Enforcement of insulation and sealing requirements through onsite inspections was uneven. Some communities had specific insulation inspections, but many inspected insulation and sealing as they could, and might not view some insulated areas that have been enclosed. Responsibility for insulation and sealing of ducts and penetrations was not consistently assigned among towns and some opportunities might be missed because of that.

Local building code officials did not use MAS*check* as a design tool or work interactively very often with builders or designers in new construction. Homeowners doing additions and renovations as their own general contractors appeared to get a great deal more attention, however, because local building code officials believed they needed the extra help to produce compliant designs.

Code officials appeared to be knowledgeable about the code, but more than 18 months after its implementation, a number of them expressed interest in refresher training for experienced staff and introductory training for new staff who were not exposed to the initial training round. Specific requests were made for checklist approaches to focus on energy issues and organize the inspection process to capture all the significant energy aspects.

2. How do designers and large and small builders view the energy code? Are they aware of the major provisions? Do they see the different code compliance approaches as a benefit in providing them with greater design flexibility? Do they regard compliance as a barrier to completing their projects on time and on budget? Do they find enforcement to be similar across jurisdictions? Does the pattern of enforcement affect decisions to pursue projects in specific localities? What could the BBRS or other parties do to assist in better use of the current code's compliance tools?

Designers, developers, and most builders were aware of the energy code provisions. In general, members of all of these groups favored the energy code provisions, and did not see the code as a significant barrier to designing and building homes their customers could afford. Designers noted the code added time (and therefore cost) to change basic specifications to meet the code. They also noted that running MAS*check* imposed a time and/or a convenience penalty on most of them because most designers use MacIntosh™ computers and MAS*check* is available only in the Windows™ operating system format.

Spec builders were more likely to see the code as imposing additional time and costs that affected the ways they have traditionally built homes. At least one small builder believed the code served to make homes less affordable to his potential customers, but this was a distinctly minority point of view.

Everyone in all market player categories agreed that enforcement varied among communities. Local building code officials indicated reasons for variations included their overriding public safety priority; variability in interest in certain energy efficiency aspects of construction, differences in knowledge levels; special local concerns; inadequate staff and time, and similar concerns. Designers and builders generally found that, though towns differed in the degree of enforcement and its emphasis, most towns had a consistent approach to the energy code; the designers and builders adjusted accordingly from community to community. Designers and builders also said they did not find variations in energy code enforcement to be much different from variations among towns in the enforcement of other aspects of the building code. During the course of these interviews we found no indications that the patterns of energy code enforcement affected developer or builder decisions to build in any particular town. As noted elsewhere, small builders and some smaller developers tended to concentrate their operations within a few towns or a region. This concentration provided them with repeat exposure to the same local building code officials, providing some certainty of how the code would be enforced in any given community.

The local building code officials indicated that it would be helpful if the BBRS provided them with—

- checklist approaches to energy code enforcement;
- refresher training and training in new materials and installation techniques;
- increased emphasis on the importance of comparing MAS*check* inputs with building plan specifications;
- a consensus of critically important energy issues to be spotlighted in inspections.

3. What designer, builder, and supplier practices have altered since the implementation of the code? Are these changes improvements? If they have experience in other states that have adopted CABO MEC 95, how do they compare that with implementation in Massachusetts? What would they change?

Aside from the use of NFRC-certified windows (discussed later), there did not appear to be a great many changes in building practices that were directly attributable to the energy code implementation. There was increased use of 2x6 framing in some areas to accommodate more wall insulation, primarily in the colder central and western parts of the state. In southeastern

Massachusetts, however, which is both the warmest part of the state and the region with the highest levels of building activity, there was mixed adoption of this measure, because climatic conditions did not always require more insulation (and the accompanying framing).

Some designers have increased their use of rigid insulation, especially in cathedral ceilings. There was some reported increase in under-floor radiant heating systems. There was some indication that installing heating systems above the efficiencies specified by the energy code had become fairly common, but this appeared to be more of a market phenomenon, and the extent of this activity could not be verified. Some players also reported increased use of multiple heating systems in larger homes to decrease duct runs and increase resident comfort.

Suppliers of general building materials and insulation have provided important support to their builder customers, particularly those suppliers who run MAS*check* for builders. Suppliers often recommend the types and quantities of materials that builders should purchase. General building materials suppliers in most areas of the state were supportive of increased 2x6 framing, but they did not appear to identify or lead their customers to other significant changes in materials. Insulation suppliers were heavily involved in the use of fiberglass batts in most applications, which appeared to be their traditional business product. Aside from advising builders on the latest techniques for full coverage and proper sealing, insulation suppliers noted mainly increases in the R-value of batts and increased use of extensions to ensure that cavities were sufficient to install larger, thicker batts.

Designers, developers and builders who had experience outside Massachusetts did not comment much on comparative implementations. Designers who had some familiarity with the IEEE2000 standard noted that that standard deals with ventilation in ways not addressed in CABO MEC 95, and were generally in favor of the updated approaches to handling ventilation in living areas.

4. How have all parties adapted to requirements concerning use of NFRC-certified windows? Are the MAScheck provisions for custom windows adequate? Do prescriptive window paths meet a real need? Has the new code affected perceived designer or customer demand for more energy-efficient windows? Are window manufacturers and supply houses providing adequate choice of conforming NFRC-labeled products?

The adoption of NFRC-certified windows for new construction appeared to be very successful. For the most part all parties had praise for this aspect of the code (with the exception of two spec builders). Some designer had concerns about unusual window designs, but, overall, designers had found they were able to work well within the code requirements. However, several developers and builders noted that the window requirements had “leveled and raised the playing field.” In the past, virtually any window could be called energy efficient. Consequently, builders who installed truly more efficient, more costly windows were at a competitive disadvantage against builders who used the cheapest product available but still claimed energy efficiency.

We found very little mention of or interest in prescriptive window paths among custom designers, and not at all among market players dealing in standard designs. Developers and builders uniformly named national brand companies as their window suppliers and none complained about any difficulties with the products they now used, except for some problems with getting certification labels to adhere early on in the changeover.

The window supply market appears to have responded well to the increased need for NFRC-certified windows. No supplier, developer, or builder cited any instances in which they were unable to obtain the particular products they needed in necessary quantities. Time to fill orders seemed to have increased early in the implementation of the new code, but in the middle of a very busy building season there did not appear to be any current supply problems.

5. To what extent have building design, development, and construction players adopted MAScheck as a preferred or commonly used tool? What features of MAScheck are particularly useful or valuable? What barriers are there within the software package or its application that inhibit its wider use? What changes might be made to widen its adoption and/or increase its effectiveness?

MAS*check* is not a design tool in the sense that it is used to determine how homes should look, be laid out, or function. The designers, as well as developers and builders, we interviewed indicated that MAS*check* was used at the end of the process to ensure energy code compliance. Custom home designs sometimes required reconfiguration of large glass areas, such as window walls, after MAS*check* was run. No one we spoke with, however, used MAS*check* in a proactive manner.

Designers suggested two changes that might improve and extend MAS*check*'s use in the design process: 1) Revise MAS*check* to be compatible with popular computer-aided design (CAD) file formats. 2) Produce a version of MAS*check* compatible with the MacIntosh operating system, since most designers still use "Macs" for their design work.

Other market players also regarded MAS*check* much the same as designers. For those developers and builders who build essentially the same home over and over again, MAS*check* had minimum value. Spec builders who built only a few homes each year and had suppliers run MAS*check* for them might be missing an opportunity because suppliers reported that builders often did not tell them what efficiency heating system would be used; in the absence of that information, suppliers used the default efficiency values and perhaps overstated the amount of needed insulation, or understated allowable window areas.

6. How important are the existing prescriptive packages? Do they cover enough 'typical' construction situations to be broadly applicable? Are the different types of players (designers, builders, suppliers) satisfied with the prescriptive solutions? For those who have experience with MAScheck and prescriptive packages what are the strengths and weaknesses of each?

Prescriptive packages did not appear to be much of a factor in current new construction. Prescriptive path solutions appeared to be more applicable to renovations and additions to existing structures in the current market. There are approximately 30 prescriptive packages in all. The number of packages to choose from can be filtered by applying climate, window area, and some other criteria, but in general market players appeared to be unaware of the packages or they ignored them.

Some players had a definite interest in a prescriptive approach to determining which energy-efficiency measures should apply to residential new construction. Those players who preferred a prescriptive approach believed it would be most valuable if applied broadly with a series of simple tables, e.g. in Climate Zone 1, "attics should always be insulated to R38," and so on. These players believed the end results would equal those obtained with MAS*check*.

7. What could be done to foster proactive attitudes toward enforcement of the energy code and use of the software tools to increase greater energy efficiency in new residential construction?

There was a generally positive attitude toward the energy code on the part of almost all market players interviewed for this study. Almost everyone interviewed believed homes built under the energy code standards will be more efficient and comfortable for residents (barring some concerns about ventilation and indoor air quality).

Local building code officials, however, generally assigned energy code enforcement a low priority among their many responsibilities. MAS*check* submissions rarely received more than cursory reviews; there was not much comparison checking between MAS*check* printouts and building plans submitted with applications; and there was very little onsite checking of the MAS*check* inputs on building sites.[9]

Increased and more thorough enforcement of the energy code requirements would be needed to increase overall compliance. However, energy code enforcement often was rated as a low priority among the multiple code responsibilities of many local building code officials.

The interviews suggested that the BBRS could take at least the following steps to improve the situation:

- Provide more training and tools to make the job easier to do in the limited time that local building code officials have available.
- Examine modifying the compliance rules to permit more use of broad prescriptive measures, in addition to the MAS*check* compliance path.

D.4 INTERVIEW INSTRUMENTS

This subsection presents the instruments that we used to conduct these market actor interviews.

[9] Data reported in the previous section of this report were consistent with this finding—less than 50% of the homes reviewed complied with the energy code.

D.4.1 Builder Instrument

Builder Interview Protocol

Interviewee ______________________________________ Date: __________________

Company ____

City/Town____

Phone ____________________________ Pager/Cell _______ _______________

Completed?

Notes: ____

Introduction:
In 1998 Massachusetts adopted a number of changes to the Massachusetts Building Code incorporating new energy efficiency guidelines for new low rise residential construction. The Board of Building Regulations and Standards (BBRS) has contracted with XENERGY Inc. and Peregrine Energy Group to conduct a review of the implementation of those new guidelines. As part of the review we are interviewing a number of people involved in housing design, development, construction, supply and code enforcement.

These interviews are confidential. We will not identify the people interviewed or the organizations involved except in the most general way, such as "owner of a construction firm in Western Massachusetts". We would like to hear your thoughts about how the new code requirements have affected your work, business, construction practices, operations, purchasing, and similar concerns. We are especially interested in learning about areas for improvement in the energy code requirements, training, compliance methods, and other aspects of the code related to energy-efficient new construction.

Thank you in advance for helping us with this review.

1. Background. What is your position in the company? What type of ownership does the company have? About how many people are employed in the company – year-round, seasonally? Does the company do anything else besides new housing construction?

About how many homes do you build in an average year? How many homes will you build in 2000? What parts of the state do you normally work in? Do you specialize in any particular housing type, size or market (production vs. spec vs. custom)? What areas do you serve? What are the typical price ranges of the homes you build?

Do you design the homes you build? If not where do your designs come from? Do you generally build strictly according to the designs or do you do much customizing? What are your most common customized features?

2. Awareness and Knowledge. How did you find out about the 1998 energy-related changes to the building code? Was that your usual channel for information about the building code? How else do you get this kind of information - what are your other sources of information on residential building? (explore role or state and regional home builders associations)

(If not mentioned) Did you know about or attend any training sessions about the code changes? Whose sessions? (could be BBRS, a supplier, intra-company, etc.). Were the sessions scheduled conveniently for you? Were they effective? Did you get a solid understanding of what the changes were and how you would be affected on a day to day basis? Did others in your industry attend, did they benefit? For the future, could you suggest any improvements for the training sessions?

Did you need and get more information at any point since? How?

3. Implementation

At this point do you feel as if you have a solid understanding of the 1998 energy requirements? Are you able to consistently apply the code's requirements to the homes you build? Do you find any parts of the code unclear or confusing?

How do you comply with the energy provisions of the code? Do you use the MAScheck software? (If not), Do you rely on someone else to run it for you? Who? And what do they do? Do you use any of the prescriptive package designs published by BBRS? Have you developed any standard designs of your own or gotten designs from others?

How do you size heating and cooling systems - do you do it yourself or rely on a supplier or subcontractor? What information is critical? Have your sizing practices changed any since the revised residential energy code was implemented?

Do you think others in the construction business – developers, suppliers, contractors, local code officials – have a solid understanding of the energy rules and practices needed to comply with them? What problems do you see or hear about from others?

Have the new window requirements generally worked well? Do suppliers help you in choosing the right NFRC-certified windows? Do they ever offer non-certified windows? (If so) under what circumstances?

4. Enforcement. In your experience is the energy code enforced evenly within towns and from town to town? (we are not asking you to name towns or officials). (If not) what kinds of differences are there? Have any differences caused problems that increased costs or delayed projects?

Are the code officials you've dealt with knowledgeable about the new energy provisions? Do you or your suppliers or subs find you disagree with local officials over code interpretation? Are there any areas that you've found to be particular problems?
How have you resolved problems arising from different interpretations of the code?

(If not mentioned among differences) What documentation for meeting the energy requirements do you present to local code departments? Are the documentation requirements pretty standard? If not, how do they differ?

What method do you typically use to show compliance with the energy code - MASCheck compliance software, pre-determined prescriptive packages, or the manual trade-off (paper and pencil) method? Do the choices for following a trade-off compliance path or choosing a prescriptive solution have any effect on enforcement? – help it or hinder it? How? Are there some areas where more flexibility would be better? Some where you'd prefer less flexibility?

Do you think there would be value to creating a statewide, uniform, mandatory application form for all new construction and rehab projects covered by the energy provisions of the code? How could it help (or not help) to improve the approval process?

Overall, with respect to enforcement, do you find things better or worse under the new residential energy provisions? How would you improve enforcement?

5. Impact/Perception. Did any of your building practices change as a result of the new energy code requirements: (examples) :framing, insulating, sealing? Use of a blower door? What about subcontractors involved in your homes: plumbers, electricians, others? Did the order or timing of any operations change as a result of the code (and if so did that add costs or lengthen the time required to complete the homes?) Have others in your industry changed their practices?

How much of the new code was already standard practice for you before the code went into effect? What about your subs and suppliers? What changes in material or labor did you have to make to ensure that your homes were in compliance?

What about your suppliers: windows, heating and cooling, framing: Have the new code requirements affected the selection, availability or price of any of these materials or equipment?

Have any changes in building practices, materials or equipment resulting from the energy code changes had an impact on building costs and price? What is that impact in dollars? What components or labor costs are most responsible for any change?

Has compliance with the new code added administrative work for you and more time or other direct costs to projects? Describe.

6. Other code effects. Since these residential energy code changes came into effect in March of 1998 have energy issues become more prominent in any aspect of building new homes? (Do code officials spend more time on reviewing energy-related parts of plans, more time and effort in inspections of sealing, insulation, etc.)?

Have these changes affected permit approval times or processes?

Do you find homebuyers are aware of the energy requirements? Do you or other builders tell buyers that your homes are more energy efficient than older homes as part of your marketing? If you do, is it effective?

7. **Assessment/Recommendations**. In general do you think the new residential energy code is an improvement over the old? In what ways? Do you think any of the changes make things worse for you as a builder or negatively affect the quality of homes being built?

What aspects of the residential new construction energy code will have the lowest levels of compliance? Which ones will be the hardest for you as a builder to implement?

What technical or administrative requirements would you add or delete from the code?

What recommendations would you make for the BBRS in the following areas?

-training (builders, code officials, suppliers, etc.)
-documentation
-uniform enforcement?
-technical support
-other

8. Conclusion. Do you have any final comments or suggestions about any aspect of the energy or its implementation?

Thank you very much for your time.

D.4.2 Designer Instrument

Designer Interview Protocol

Interviewee ____ Date: __________________

Company ____

City/Town____State______________

Phone ____________________________ Pager/Cell _______ ______________

Completed?

Notes: ____

Introduction:
In 1998 Massachusetts adopted a number of changes to the Massachusetts Building Code incorporating new energy efficiency guidelines for new low-rise residential construction. The Board of Building Regulations and Standards (BBRS) has contracted with XENERGY Inc. and Peregrine Energy Group to conduct a review of the implementation of those new guidelines. As part of the review we are interviewing a number of people involved in housing design, development, construction, supply and code enforcement.

These interviews are confidential. We will not identify the people interviewed or the organizations involved except in the most general way, such as "owner of a small architectural firm in Western Massachusetts". We would like to hear your thoughts about how the new code requirements have affected your work, business, design practices, operations, clients, and similar concerns. We are especially interested in learning about areas for improvement in the energy code requirements, training, compliance methods, and other aspects of the code related to energy-efficient new construction.

Thank you in advance for helping us with this review.

1. Background. What is your position in the company? About how many people are employed in the company? What types of buildings does the company design? Does the company do design/build work? What percentage of your design work is residential 1 & 2 family buildings? Of these, what percentage are built in Mass.?

What kinds of residential designs does your company do? Do you specialize in any particular segments of the residential market? Do you do custom design work? Who are your primary customers - homeowners, builders, developers? On your typical customer's lists of priorities, where would you say energy efficiency stands? Has that standing changed much over the last 10 years?

2. Awareness and Knowledge. How did you find out about the 1998 energy-related changes to the building code? Was that your usual channel for information about the building code? How else do you get this kind of information?

(If not mentioned) Did you know about or attend any training sessions about the code changes? Whose sessions? (could be BBRS, a supplier, intra-company, etc.). Did you get a solid understanding of what the changes were and how you would be affected on a day to day basis? Did you need and get more information at any point since?

3. Implementation
At this point do you feel as if you have a solid understanding of the 1998 energy requirements? Are you able to consistently apply the code's requirements to the homes you design? Do you find any parts of the code unclear or confusing?

Do you use the MAScheck software at any stage of the design process? If so, how? (home design, check on compliance, develop materials specs, etc.) (If not), Do you rely on someone else to run it for you? Who? And what do they do? Do you use any of the prescriptive package designs? How often do you use the Manual Trade-off (Paper and Pencil) approach, or building simulation models?

Do you include heating and cooling systems in your designs? How do you size them?- Do you do it yourself or rely on a supplier or subcontractor? What information is critical? Have your sizing practices changed any since the revised energy code was implemented in 1998?

Do you think others in the construction business – developers, suppliers, contractors, local code officials – have a solid understanding of the energy rules and practices needed to comply with them? What residential energy code-related problems do you see or hear about from others?

Have you been able to smoothly incorporate NFRC-certified windows into your designs? Have you experienced any limitations in the window design choices available since the new window labeling regulations have come into effect? What problems?

4. Enforcement. Do you deal with code officials in the normal course of your work? In your experience is the energy code enforced evenly within towns and from town to town? (we are not asking you to name towns or officials). (If not) what kinds of differences are there? Have you sometimes had to tailor designs to meet local interpretations of the energy code for a specific town? Have any differences caused problems that increased costs or delayed projects? –

Are the code officials you've dealt with knowledgeable about the new energy provisions? Do you or your suppliers or subs find you disagree with local officials over code interpretation? Are there any areas that you've found to be particular problems?
How have you resolved problems arising from different interpretations of the code?

(If not mentioned among differences) What documentation for meeting the energy requirements do you present to local code departments? Are the documentation requirements pretty standard? If not, how do they differ?

Does the code's flexibility help or hinder enforcement? How? Are there some areas where more flexibility would be better? Some where you'd prefer less flexibility?

Do you think there would be value to creating a statewide, uniform, mandatory application form for all new construction and rehab projects covered by the energy provisions of the code? How could it help (or not help) to improve the approval process?

5. Impact/Perception. Have any of your design specifications or practices changed as a result of the new code requirements: (examples) :framing, insulating, sealing? Use of a blower door? To the best of your knowledge has the order or timing of any parts of the design, materials procurement, or construction processes changed as a result of the code. If so, did that add costs or lengthen the time required to complete the homes? (unless they do design/build they may not be able to respond to this question)

What about your suppliers: windows, heating and cooling, framing: Have the new code requirements affected the selection, availability or price of any of these elements?

Have any changes in building designs, materials or equipment resulting from the energy code changes had an impact on building costs and price? What is that impact in dollars? What labor or material components are most responsible for any changes in cost?

How much of the new code was already standard practice for you before the new residential energy code went into effect? What about developers, contractors suppliers and others in new home construction?

Has compliance with the new code added administrative work for you and more time or other direct costs to projects? Describe.

Overall, with respect to code enforcement, do you find things better or worse under the new energy provisions? How would you improve enforcement?

6. Other code effects. Since these code changes came into effect have energy issues become more prominent in any aspect of designing new homes? Have these changes affected permit approval times or processes?

Do you find homebuyers are aware of the revised energy requirements? Do you or other designers tell buyers that your homes are more energy efficient than older homes as part of your marketing? If you do, is it effective? Do new homeowners typically request that you consider energy efficiency when developing a plan for them? Are there any specific features they request?

7. Assessment/Recommendations. In general do you think the new code is an improvement over the old? In what ways? Do you think any of the changes make things worse for you as a designer or negatively affect the quality of homes being built?

What aspects of the code will have the lowest levels of compliance? Which ones will be the hardest for you as a designer to implement?

What technical or administrative requirements would you add or delete from the code?

What recommendations would you make for the BBRS in the following areas?

-training (designers, code officials, suppliers, etc.)
-documentation
-uniform enforcement?
-technical support
-other

8. Conclusion. Do you have any final comments or suggestions about any aspect of the energy code or its implementation?

Thank you very much for your time.

D.4.3 Developer Instrument

Developer Interview Protocol

Interviewee ____ Date: __________________

Company ____

City/Town____State__________________

Phone ______________________________ Pager/Cell _______ _______________

Completed?

Notes: ____

Introduction:
In 1998 Massachusetts adopted a number of changes to the Massachusetts Building Code incorporating new energy efficiency guidelines for new low-rise residential construction. The Board of Building Regulations and Standards (BBRS) has contracted with XENERGY Inc. and Peregrine Energy Group to conduct a review of the implementation of those new guidelines. As part of the review we are interviewing a number of people involved in housing design, development, construction, supply and code enforcement.

These interviews are confidential. We will not identify the people interviewed or the organizations involved except in the most general way, such as "owner of a construction firm in Western Massachusetts". We would like to hear your thoughts about how the new code requirements have affected your work, business, construction practices, operations, purchasing, and similar concerns. We are especially interested in learning about areas for improvement in the code, training, compliance methods, and other aspects of the code related to energy-efficient new residential construction.

Thank you in advance for helping us with this review.

1. Background. What is your position in the company? What type of ownership does the company have? About how many people are employed in the company – year-round, seasonally? Does the company do anything else besides new housing construction? Are you active outside of Massachusetts? Where else?

About how many homes do you build in Massachusetts in an average year? Nationally? How many homes will you build in Massachusetts 2000? What parts of the state are you most active in? Do you specialize in any particular housing type, size or market? What are the typical price ranges of the homes you build?

Do you design the homes you build? If not, where do your designs come from? Do you generally build strictly according to the designs or do you do much customizing? (If a regional or national developer: To what extent do you customize your plans for the Massachusetts market?) What are your most common customized features?

Do you have your own construction crews? Do you contract any work with local builders? How does the contractual relationship with builders work – are they responsible for code compliance? Permits? Inspections? Do you actively inspect and/or oversee their work? Who in the organization is responsible for code compliance issues, particularly energy code issues?

2. Awareness and Knowledge. How did you find out about the 1998 energy-related changes to the building code? Was that your usual channel for information about the building code? How else do you get this kind of information? Is someone (else) in your organization overall responsible for code compliance? What are your other sources of information on residential building? (explore role of state and regional home builders associations)

(If not mentioned) Did you know about or attend any training sessions about the code changes? Whose sessions? (could be BBRS, a supplier, intra-company, etc.). Were the sessions scheduled conveniently for you? Were they effective? Did you get a solid understanding of what the changes were and how you would be affected on a day to day basis? What about others in your industry –Did they attend, did they benefit? For the future, could you suggest any improvements for the training sessions?

Did you need and get more information at any point since? How?

3. Implementation

At this point do you feel as if you have a solid understanding of the 1998 energy requirements? Are you able to consistently apply the code's requirements to the homes you build? Do you find any parts of the code unclear or confusing?

How do comply with the energy provisions of the code? Do you use the MAScheck oftware? If so, how? (home design, check on compliance, develop materials specs, etc.) (If not), Do you rely on someone else to run it for you? Who? And what do they do? Do you use any of the prescriptive package designs published by BBRS? Have you developed any standard designs of your own or gotten designs from others?

How do you size heating and cooling systems - do you do it yourself or rely on a supplier or subcontractor? What information is critical? Have your sizing practices changed any since the revised residential energy code was implemented in 1998?

Do you think others in the construction business – developers, suppliers, contractors, local code officials – have a solid understanding of the energy rules and practices needed to comply with them? What problems do you see or hear about from others?

Have the new window requirements generally worked well? Do suppliers help you in choosing the right NFRC-certified windows? Do they ever offer non-certified windows? (If so) under what circumstances?

4. Enforcement. In your experience is the energy code enforced evenly within towns and from town to town? (we are not asking you to name towns or officials). (If not) what kinds of differences are there? Have any differences caused problems for that increased costs or delayed projects?

Are the code officials you've dealt with knowledgeable about the new energy provisions? Do you or your suppliers or subs find you disagree with local officials over code interpretation? Are there any areas that you've found to be particular problems?
How have you resolved problems arising from different interpretations of the code?

(If not mentioned among differences) What documentation for meeting the energy requirements do you present to local code departments? Are the documentation requirements pretty standard? If not, how do they differ?

What method do you typically use to show compliance with the energy code - MAScheck compliance software, , pre-determined prescriptive packages, or the manual trade-off? Do the choices for following a trade-off compliance path or choosing a prescriptive solution have any effect on enforcement? – help it or hinder it? How? Are there some areas where more flexibility would be better? Some where you'd prefer less flexibility? (If they use MAScheck) - what do you think of MAScheck as a compliance tool?

Overall, with respect to enforcement, do you find things better or worse under the new energy provisions? How would you improve enforcement?

5. Impact/Perception. Did any of your building practices change as a result of the new energy code requirements: (examples) :framing, insulating, sealing? Use of a blower door? If so which ones and how did they change? What about subcontractors involved in your homes: plumbers, electricians, others? Did the order or timing of any operations change as a result of the code (and if so did that add costs or lengthen the time required to complete the homes?)? Have others in your industry changed their practices?

How much of the new code was already standard practice for you before the code went into effect? What about your subs and suppliers? What changes in materials or labor did you have to make to ensure that your homes were in compliance?

What about your suppliers: windows, heating and cooling, framing: Have the new residential code requirements affected the selection availability or price of any of these elements?

Have any changes in building practices, materials or equipment resulting from the energy code changes had an impact on building costs and price? What is that impact in dollars? What components or labor costs are most responsible for any change?

Has compliance with the new code added administrative work for you and more time or other direct costs to projects? Describe.

6. Other code effects. Since these residential energy code changes came into effect in1998 have energy issues become more prominent in any aspect of building new homes? (Do code officials spend more time on reviewing energy-related parts of plans, more time and effort in inspections of sealing, insulation, etc.)?

Have these changes affected permit approval times or processes?

Do you find homebuyers are aware of the energy requirements? Do you or other builders tell buyers that your homes are more energy efficient than older homes as part of your marketing? If you do, is it effective?

7. **Assessment/Recommendations**. In general do you think the new code is an improvement over the old? In what ways? Do you think any of the changes make things worse for you as a builder or negatively affect the quality of homes being built?

What aspects of the residential energy code for new construction have the lowest levels of compliance? Which ones are the hardest for you as a developer to implement?

What technical or administrative requirements would you add or delete from the code?

What recommendations would you make for the Massachusetts Board of Building Regulations and Standards in the following areas?

-training (builders, code officials, suppliers, etc.)
-documentation
-uniform enforcement
-technical support
-other

8. Conclusion. Do you have any final comments or suggestions about any aspect of the energy or its implementation?

Thank you very much for your time.

D.4.4 Local Code Official Instrument

Local Code Official Interview Protocol

Interviewee ________________________________ Date: _______________

Company ____

Town/City____

Phone ________________________ Pager/Cell ______ ____________

Completed?

Notes: ____

Introduction:
In 1998 Massachusetts adopted a number of changes to the Massachusetts Building Code incorporating new energy efficiency guidelines for new low-rise residential construction. The Board of Building Regulations and Standards (BBRS) has contracted with XENERGY Inc. and Peregrine Energy Group to conduct a review of the implementation of those new guidelines. As part of the review we are interviewing a number of people involved in housing design, development, construction, supply and code enforcement.

These interviews are confidential. We will not identify the people interviewed or the organizations involved except in the most general way, such as “a local code official”. We would like to hear your thoughts about how the new code requirements have affected your work in code enforcement, as well as business, construction practices, operations, purchasing, and other aspects of new home construction. We are especially interested in learning about ideas for improvement in the energy code requirements, training, MAScheck compliance software, prescriptive packages, and other aspects of the code related to energy-efficient new construction.

Thank you in advance for helping us with this review.

1. Background. What is your position in the town? What are your responsibilities with respect to building code enforcement? Are there other staff with building code enforcement responsibilities? Is your town position a full time position? Do you provide code enforcement in other towns What other work do you do?

About how many homes will be built in _[NAME of MUNICIPALITY]______ this calendar year? How many have been built since the energy-related code revisions went into effect in March of 1998? What types of homes are being built? (single, 2-fam, condos, etc.). How large is the average new home? What's a typical range of prices?

2. Awareness and Knowledge. How did you find out about the 1998 energy-related changes to the building code? Was that your usual channel for information about the building code? How else do you get this kind of information? (if not already addressed) - What information did you receive from the regional code officials organization From the BBRS?

Among others in the industry, developers, builders, contractors, code officials, what is your impression about:

- awareness of the code energy provisions;
- level of knowledge;
- how they learned about the code and its provisions

(If not mentioned) Did you know about or attend any training sessions about the code changes? Whose sessions? (could be BBRS, a supplier, intra-company, etc.). Were the BBRS sessions scheduled conveniently for you? Were they effective? Did you get a solid understanding of what the changes were and how you would be affected on a day to day basis? Did you need and get more information at any point since?

3. Implementation

How do you evaluate new home plans for compliance with the energy code? Does your review of proposed new homes include a review of heating and cooling system sizing?

What documentation do you require for proposed new home compliance with the energy provisions of the code ? (be detailed)

How often do builders submit MAScheck runs on proposed homes? Do they submit electronic, printed copies or both? How often do builders use one of the prescriptive package designs? Do many builders use the Manual Trade-off ("Paper and Pencil") approach?

When you get MAScheck runs as compliance documentation, do you require any additional documentation as support? (i.e.- copies of "take-off" calculations, window schedules, etc.) Do you (or other town staff) run the MAScheck software on plans submitted by builders? Do you ever re-run MAScheck to confirm a submitted run, or on homes as- built? (re-run the home to reflect as-built, vs as-designed)

For sizing heating and cooling systems, is the critical information readily available from builders, plumbers, suppliers? Have code requirements for sizing changed? Have your documentation requirements changed since the code revisions? (Prompt for reference to Manual J if not mentioned)

Have the new window requirements generally worked well? Are builders choosing NFRC-certified windows? How do they document use of certified windows? Do they ever use non-certified windows? (If so) under what circumstances?

At this point do you feel you are able to consistently apply the code's energy requirements to the homes proposed and built in [NAME of MUNICIPALITY]_________? Do you find any parts of the code unclear or confusing? (If so, what areas need clarification or further work?)

From contact with builders, and code officials in other communities, do you believe the energy-related code provisions for new construction are understood and enforced pretty consistently among the cities and towns? How do towns differ?

Do you think others in the construction business – developers, suppliers, contractors, have a solid understanding of the energy rules and practices needed to comply with them? What problems do you see or hear about from others? Is documentation compliance easier or harder on the whole now?

Do the choices for following a trade off approach or choosing a prescriptive package solution have any effect on enforcement? – help it or hinder it? How? Are there some areas where more flexibility would be better? Some where you'd prefer less flexibility? Do you find MAScheck to be a plus or a minus from a code officials perspective?

4. Impact/Perception. What building practices have changed as a result of the new code requirements: (examples) :framing, insulating, HVAC equipment efficiencies, sealing? Use of a blower door? What about subcontractor practices?: plumbers, electricians, others?

Have any changes in building practices, materials or equipment resulting from the energy code changes had an impact on building costs and price? Can you estimate that impact in dollars?

Are there building practices or materials specified by the new code that were already standard practice before the code went into effect? Which ones? (If so, would you say that was only in your town, or was it more widespread?

Has compliance with the new code added administrative work for you or affected the time you (or your staff) need to devote to each new home or project? Describe.

Overall, with respect to enforcement, do you find things better or worse under the new energy provisions? How would you improve enforcement?

5. Other code effects. Since these code changes came into effect have energy issues become a more prominent aspect of building new homes? (Do you spend more time on reviewing energy-related parts of plans, more time and effort in inspections of sealing, insulation, etc. than you did previously)?

Have these changes affected permit approval times or processes?

Do you think homebuyers are aware of the energy requirements? Do you see evidence that builders or real estate agents tell buyers that homes being built now are more energy efficient than older homes as part of their marketing? If they do, is it effective? Have you noticed any changes in buyer interest in energy efficiency since the increase in home heating oil prices this Winter and Spring?

6. Assessment/Recommendations. In general do you think the new code is an improvement over the old? In what ways? Do you think any of the changes make things worse for you as a code enforcement official?

What energy-related aspects of the residential building code require the most vigorous code enforcement on your part? Which ones are the hardest for builders to implement?

What technical or administrative requirements would you add or delete from the code?

What recommendations would you make for the BBRS in the following areas?

-training (builders, code officials, suppliers, etc.)
-documentation
-uniform enforcement?
-technical support
-other

Do you think there would be value to creating a statewide, uniform, mandatory application form for all new construction and rehab projects covered by the energy provisions of the code? How could it help (or not help) to improve the approval process?

7. Conclusion. Do you have any final comments or suggestions about any aspect of the energy or its implementation?

Thank you very much for your time.

D.4.5 State Inspector Discussion Guide

1. Introductions, Description of the qualitative parts of the project.
2. Descriptions by inspectors of what they do generally and what kind of involvement they have with residential new construction.
3. **General question and discussion:** How are builders and local code officials complying with the energy code requirements? How deep is the knowledge and interest in energy efficiency? Where does energy fit among their other priorities (and what are their main priorities?). How great an emphasis should be placed on energy in the inspectors' views and what do inspectors do to foster an appropriate level of effort by builders, code officials and others?
4. How effective is MASCheck as an aid to code compliance? Is it the right tool for the job? How does it's level of complexity match the needs to address the code requirements? – is too simple, too complex?
5. What particular problems regarding the implementation of the energy code have been posed to the inspectors? Who poses the problems? Are these problems isolated or pervasive? Are inspectors able to assist with the problems posed within the code as it currently exists and is implemented to their satisfaction?
6. Are there changes they would like to see that would improve the houses being built and/or code enforcement? What are they?
7. Final suggestions, thoughts, et cetera.

D.4.6 Supplier Instrument

Supplier Interview Protocol

Interviewee ______________________________________ Date: __________________

Company ____

City/Town____

Phone ______________________________ Pager/Cell _______ _______________

Completed?

Notes: ____

Introduction:
In 1998 Massachusetts adopted a number of changes to the Massachusetts Building Code incorporating new energy efficiency guidelines for new low-rise residential construction. The Board of Building Regulations and Standards (BBRS) has contracted with XENERGY Inc. and Peregrine Energy Group to conduct a review of the implementation of those new guidelines. As

part of the review we are interviewing a number of people involved in housing design, development, construction, supply and code enforcement.

These interviews are confidential. We will not identify the people interviewed or the organizations involved except in the most general way, such as “building supply company owner”. We would like to hear your thoughts about how the new code requirements have affected your work, business, construction practices, operations, purchasing, and similar concerns. We are especially interested in learning about areas for improvement in the energy code requirements, training, compliance methods, and other aspects of the code related to energy-efficient new construction.

Thank you in advance for helping us with this review.

1. Background. What is your position in the company? What type of ownership does the company have? About how many people are employed in the company – year-round, seasonally?

What kinds of building supplies, equipment and/or services do you sell for residential new construction? Who are your customers? What areas do you service? How many locations do you have in Massachusetts? New England? What portion of your sales come from single family home new construction (or from contractors if we are more likely to get a meaningful response)?

2. Awareness and Knowledge. How did you find out about the 1998 energy-related changes to the building code? Was that your usual channel for information about the building code? How else do you get this kind of information? What’s your impression of how your customers know about it?

(If not mentioned) Did you know about or attend any training sessions about the code changes? Whose sessions? (could be BBRS, a supplier, intra-company, etc.). Were the sessions scheduled conveniently for you? Were they effective? Did you get a solid understanding of what the changes were and how you would be affected on a day to day basis? Did others in your industry attend, did they benefit? For the future, could you suggest any improvements for the training sessions?

3. Implementation

At this point do you feel as if you have a solid understanding of the 1998 energy requirements? Do you think others in the residential construction business – developers, designers, suppliers, contractors, local code officials – have a solid understanding of the energy rules and practices needed to comply with them? What energy code-related problems do you see or hear about from others?

Do you help customers choose materials, equipment, appliances? Do you provide them with advice or assistance for complying with the energy code? (If you do), do you provide any assistance involving the use of MAScheck, the computerized energy code compliance software -

What do you do? Do you charge for these services? Are your customers eager for help? What reasons do customers give for requesting help?

(If you do MAScheck calculations) are you able to consistently and readily develop passing plans? What percentage of plans you review fail on the first pass? What types of changes are typically done to achieve compliance? Do you find any parts of the code unclear or confusing?

Do you use any of the prescriptive package designs as a sales tool? Or actually provide or sell any prescriptive packages of your own design?

Do you sell heating or cooling systems for residential new construction? Who determines sizing – (If you do, or if you help) How do you size them?-(probe for Manual J if not mentioned and the extent of oversizing) do you do it yourself or rely on someone else? Have your sizing practices changed any since the code was implemented?

Has the code requirement for NFRC-certified windows affected your business in any way? Are there adequate choices and quantities of qualified windows to meet demand? What kinds of problems have you or your customers experienced?

Overall, are there sufficient builder choices for using the MAScheck compliance software or the prescriptive packages to determine energy code compliance? Are there some areas where more flexibility would be better? Some where you'd prefer less flexibility?

4. Enforcement. Do you deal with code officials in the normal course of your work? Do you hear about code enforcement issues from your customers?

From your direct or indirect knowledge, are the residential code officials knowledgeable about the new energy provisions? Do the energy provisions appear to be enforced consistently and uniformly among cities and towns? Are you aware of or been involved with any problems in code interpretation by local officials? What kinds of problems? How were they resolved?

Do you assist your customers with preparing energy-related documentation for local code officials? What sorts of documentation? Are the documentation requirements pretty standard? If not, how do they differ among communities?

Overall, with respect to enforcement, do you find things better or worse under the new energy provisions? How would you improve enforcement?

5. Impact/Perception. Have any design specifications or practices changed as a result of the new code requirements: (examples) :framing, insulating, sealing? Use of a blower door? If yes, describe the change. To the best of your knowledge has the order or timing of any parts of residential construction changed as a result of the code and if so did that add costs or lengthen the time required to complete the homes?

Have the new code requirements affected the selection, availability or price of any of supplies you sell for residential new construction? Have you changed any of your stocking practices as a result of the energy code requirements – (If so), has that affected the products you offer to customers other than builders of residential new construction? (spillover effects?)

Have any changes in building designs, materials or equipment resulting from the energy code changes had an impact on building costs and price? What is that impact?

In your experience, how much of the new code was already standard practice by your customers before the code went into effect? Were some of the new requirements standard practice for some builders, or more common in some communities or markets? (potential difference by markets - geography, spec vs. custom, housing cost, etc.)

Has compliance with the new code added any administrative work for you and more time or other direct costs to the goods and services you sell? Describe.

6. Other code effects. Since these code changes came into effect have energy issues become more prominent in building new homes? Have these changes affected permit approval times or processes?

Since these code changes came into effect have energy issues become more prominent in marketing new homes? Did this winter's run-up in oil prices show up in the kinds of energy choices builders are making now?

7. Assessment/Recommendations. In general do you think the new code is an improvement over the old? In what ways? Do you think any of the changes make things worse for you as a supplier or negatively affect the quality of homes being built?

What aspects of the code will have the lowest levels of compliance ? Which ones will be the hardest for builders to implement?

What technical or administrative requirements would you add or delete from the code?

What recommendations would you make for the Massachusetts Board of Building Regulations and Standards in the following areas?

- -training (designers, code officials, suppliers, etc.)
- -documentation
- -uniform enforcement
- -technical support
- -other

8. Conclusion. Do you have any final comments or suggestions about any aspect of the energy code or its implementation?

Thank you very much for your time.

D.4.7 Interviewee Information

The following tables present summary information about the location of the market actors interviewed for this study and the interview dates.

Local Building Code Inspectors

Local code	County	Climate Zone	Interview Date
Inspector 1	Bristol	12	10-Jul-00
Inspector 2	Bristol	12	11-Jul-00
Inspector 3	Plymouth	12	11-Jul-00
Inspector 4	Essex	13	12-Jul-00
Inspector 5	Essex	13	12-Jul-00
Inspector 6	Middlesex	13	12-Jul-00
Inspector 7	Bristol	12	14-Jul-00
Inspector 8	Worcester	14	14-Jul-00
Inspector 9	Middlesex	13	18-Jul-00
Inspector 10	Hampshire	14	25-Jul-00
Inspector 11	Hampshire	14	25-Jul-00

District State Building Official Discussion Group

Inspector	Town	County	Climate Zone	Interview Date
DSBO 1			14	25-Jul-00
DSBO 2			14	25-Jul-00
DSBO 3			14	25-Jul-00

Designers

Designer	Town	County	Climate Zone	Interview Date
Designer 1	Easton	Bristol	12	19-Jul-00
Designer 2	Worcester	Worcester	14	24-Jul-00
Designer 3	Wrentham	Norfolk	13	26-Jul-00
Designer 4	Cambridge	Middlesex	13	4-Aug-00
Designer 5	Great Barrington	Berkshire	14	8-Aug-00
Designer 6	Wellesley	Middlesex	13	9-Aug-00
Designer 7	Medford	Middlesex	13	11-Aug-00
Designer 8	Boston	Suffolk	13	16-Aug-00

Suppliers

Supplier	Town	County	Climate Zone	Interview Date
Supplier 1	Ashland	Middlesex	13	18-Jul-00

Supplier 2	Natick	Middlesex	13	18-Jul-00
Supplier 3	Stoughton	Norfolk	13	19-Jul-00
Supplier 4	Fall River	Bristol	12	20-Jul-00
Supplier 5	Swansea	Bristol	12	20-Jul-00
Supplier 6	Chicopee	Hampden	14	27-Jul-00
Supplier 7	Beverly	Essex	13	4-Aug-00
Supplier 8	Woburn	Middlesex	13	7-Aug-00
Supplier 9	Taunton	Bristol	12	7-Aug-00

Developers

Developer	Town	County	Climate Zone	Interview Date
Developer 1	Marlborough	Middlesex	13	27-Jul-00
Developer 2	Shrewsbury	Worcester	14	8-Aug-00
Developer 3	Sudbury	Middlesex	13	10-Aug-00
Developer 4	Somerville	Middlesex	13	16-Aug-00
Developer 5	Brockton	Plymouth	12	17-Aug-00
Developer 6	Charlton	Worcester	14	12-Sep-00
Developer 7	Medfield	Middlesex	13	12-Sep-00
Developer 8	Norwell	Plymouth	12	15-Sep-00

Builders

Builder	Town	County	Climate Zone	Interview Date
Builder 1	Mansfield	Bristol	12	2-Aug-00
Builder 2	Waltham	Middlesex	13	2-Aug-00
Builder 3	Somerset	Bristol	13	4-Aug-00
Builder 4	Acton	Middlesex	13	7-Aug-00
Builder 5	N. Easton	Bristol	12	10-Aug-00
Builder 6	Springfield	Hampden	14	15-Aug-00
Builder 7	Acton	Middlesex	13	16-Aug-00
Builder 8	Fairhaven	Bristol	12	23-Aug-00
Builder 9	Wrentham	Norfolk	13	28-Aug-00
Builder 10	Easton	Bristol	12	8-Sep-00
Builder 11	Lawrence	Essex	13	8-Sep-00
Builder 12	Northampton	Hampshire	14	20-Sep-00