Massachusetts Residential New Construction Net Impacts Report

FINAL

1/27/2014

Submitted to:
Berkshire Gas
Cape Light Compact
Columbia Gas of Massachusetts
National Grid USA
New England Gas
NSTAR Electric and Gas
Unitil
Western Massachusetts Electric

Submitted by:
NMR Group, Inc.

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

Contents

Tables

Executive Summary

The Massachusetts Residential New Construction (MA RNC) Net Impacts study was designed to estimate the net impacts that may be attributed to the Massachusetts Residential New Construction Program for single-family homes. Net impacts encompass both free-ridership for homes built through the Program and non-participant spillover for homes that did not participate in the Program in 2011 assuming the Program had not existed during the years 2004 through 2011. Net impacts were divided by the Program's claimed savings to obtain net-to-gross ratios, both for the Program overall and for different fuels.

Methodology

The study used a multi-step methodology consisting of a builder survey, a Delphi study involving a panel of experts in energy-efficient new construction, modeling of home energy usage under the counterfactual assumption that the Program had not existed from 2004 to 2011, and comparing the as-built modeled energy usage to the estimate from the counterfactual models. This approach was developed to account for as many factors as possible that might have influenced the adoption of energy-efficient construction practices.

The first step was an extensive on-line survey of 147 homebuilders exploring the factors that influenced changes to their building practices between 2004 and 2011. The builder survey findings, as well as the actual energy-efficiency values for program homes and 100 non-program homes that had participated in the 2011 Baseline, were presented to a panel of 14 experts in energy-efficient new construction using the Delphi method, an iterative process in which the panelists participated in two rounds of questions. The Delphi panel questionnaires also included extensive supporting materials documenting changes in building practices and codes between 2004 and 2011 and Program activities such as incentives, training, marketing, and code support that may have influenced those changes. The Delphi panel estimated the energy efficiency values that would have existed in 2011 in the absence of the Program for 12 measures—both for homes that had gone through the Program and those that had not participated.

Four data sets, two each for program and non-program homes, were generated to reflect the Delphi panel estimates under the counterfactual assumption. Within these data sets, each sampled home was provided counterfactual efficiency values for each of the building components considered by the Delphi panel. Modeling two counterfactual runs (two different estimates of energy consumption in absence of the Program) rather than one allows for a greater combination of interactive effects among the models and ultimately results in a more robust net savings estimate for the Program.

The original REM/Rate® models for both program and non-program homes (referred to as the "as-built" models) were compared to the counterfactual models to calculate net savings. Net savings for program and non-program homes were then multiplied by the corresponding numbers of single-family homes built in 2011. These savings were divided by claimed Program savings to calculate the net-to-gross ratio.

Findings

The study found substantial net savings for the single-family component of the Massachusetts Residential New Construction Program. The Delphi panel estimated that, if the Program had not existed between 2004 and 2011, homes completed in 2011 would have been quite a bit less efficient—both those that would have participated in the Program and those that would not have participated. While the Program has a moderate free-ridership rate (0.53), non-participant spillover is quite high (1.39) yielding a net-to-gross ratio of 1.87, when assessing savings using the fuel neutral metric of MMBtu. Even at the low end of the 95% confidence interval around the estimates, the net-to-gross ratio is substantial at 1.37. Table ES-1 presents claimed program savings, counter factual program and non-program savings, free ridership, non-participant spillover and the net-to-gross ratio.

Table ES-1: Net Savings and Net-to-Gross Ratio

(MMBtu)

Confidence Interval	Claimed Program Savings	Counterfactual Program Savings	Counterfactual Non-Program Savings	Free Ridership	Non-Participant Spillover	Net-to-Gross
*n**	*1,180/4,465*					
Low CI	54,752	22,774	62,284	0.38	0.92	1.37
Mid-Point	62,776	29,748	87,561	0.53	1.39	1.87
High CI	74,812	37,677	114,839	0.67	1.87	2.36

*Number of program homes/number of non-program homes

There are several noteworthy findings in addition to the net-to-gross ratio achieved by the Program.

- Non-program homes are responsible for 75% of net savings in terms of MMBtu, 68% of electric savings, and 71% of natural gas savings.
- The Delphi panelists noted that the program has had a particularly strong effect on air infiltration, duct leakage, lighting, insulation installation grades, and some heating system efficiencies.
- When assessing net savings using the fuel-neutral metric of MMBtu, natural gas is the fuel with the most net savings, followed by propane and then electricity.
- Lighting is responsible for 61.5% of all electric net savings. Program lighting is responsible for 25.7% of all electric savings while non-program lighting is responsible for 35.8%. It should also be noted that lighting accounts for 80.4% of the electric savings in program homes, and 52.6% of the electric savings in non-program homes.

The following recommendations emerge from the findings of this study:

- *Assess the net impacts of the Program's multifamily component.* While it may be difficult to assess net impacts in the low-rise multifamily market without a baseline study, the high-rise market may be examined after its planned baseline is completed. Since this market has been addressed by different programs, both commercial and residential, over the past few years, it would be necessary to consider the actions of the different programs before trying to quantify net impacts.
- *Continue to conduct baseline studies of non-program homes.* Since most of the homes being built in Massachusetts do not participate in the Program, non-participant spillover is an important component of the Program's net impacts. With the expanding number of stretch code communities and the introduction of IECC 2012, it is important to maintain up-to-date information on non-program home characteristics.
- *Continue to emphasize practices such as quality insulation installation in trainings.* The comparison between program home and non-program home insulation installation grades illustrates the dramatic effect the Program has had on building practices, probably more than would be apparent when examining only the equipment and materials used.
- *Continue to carefully document any and all program actions that may affect the market.* Delphi panels may be used in future efforts to estimate program net impacts and it is important to provide a thorough record of the Program's involvement in training, marketing, code support, and other areas, particularly where nonparticipants are affected.

1 Introduction

The Massachusetts Residential New Construction (MA RNC) Net Impacts study is designed to estimate the net impacts that may be attributed to the Massachusetts Residential New Construction Program, formerly known as the Massachusetts New Homes with ENERGY STAR® (ESH) Program for single-family homes. This is a multi-step study consisting of a builder survey, a Delphi study involving a panel of experts in energy-efficient new construction, modeling of home energy usage under the counterfactual assumption that the Program had not existed from 2004 to 2011, and comparing the as-built modeled energy usage to the estimate from the counterfactual models which used the Delphi panel results. This approach was developed to account for as many factors influencing the adoption of energy-efficient construction practices as possible—both for homes that participated in the Program and homes that were built outside the Program. Among these factors are the incentives offered by the Program, training both within and outside the Program, changing building codes, Program support of the new codes, subcontractor and supplier availability, and customer demand.

1.1 Homebuilder Survey

The first step in this project was an extensive on-line survey of 147 homebuilders exploring the factors that influenced changes to their building practices between 2004 and 2011. The builder survey is described in more detail in Section 2.

1.2 Delphi Panel

The builder survey findings, as well as other supporting materials were presented to a panel of 14 experts in energy-efficient new construction using the Delphi method, an interactive process in which the panelists participated in two rounds of questions. The Delphi panel estimated the energy efficiency values that would have existed in 2011 in the absence of the Program for 12 measures—both for homes that had gone through the Program and those that had not participated. The Delphi panel process is described in more detail in Section 3 and the panel results are presented in Section 4.

1.3 Modeling Homes with Counterfactual Energy Efficiency Values

Four data sets, two each for program and non-program homes, were generated to reflect the Delphi panel estimates under the counterfactual assumption. Within these data sets, each sampled home was provided counterfactual efficiency values for each of the building components considered by the Delphi panel. The efficiency values assigned to each home were unique in each of the four data sets, allowing two counterfactual models to be developed for both program and non-program samples. Modeling two counterfactual runs (two different estimates of energy consumption in absence of the Program) rather than one allows for a greater combination of interactive effects among the models and ultimately results in a more robust net savings estimate for the Program. The process of generating values and modeling under counterfactual assumptions is presented in more detail in Section 5.

1.4 Determining Net Savings and the Net-to-Gross Ratio

The original REM/Rate models[1] for both program and non-program homes (referred to as the "as-built" models) were compared to the counterfactual models to calculate net savings. Specifically, the energy consumption values from the as-built models were subtracted from the averaged energy consumption values of the two corresponding counterfactual models to estimate savings attributable to program homes and non-program homes. To assess the statistical uncertainty surrounding the estimated savings, 95% confidence intervals were constructed around the program and non-program savings estimates. More details on calculating net savings are provided in Section 5.

Net savings for program and non-program homes were then multiplied by the corresponding numbers of single-family homes built in 2011. These savings were divided by claimed Program savings to calculate the net-to-gross ratio. This process is described in detail in Section 6.

[1] REM/Rate is a residential energy analysis software that is commonly used to model the performance of residential buildings; the software is most notably used by the ENERGY STAR® Homes program.

2 Homebuilder Survey

One-hundred-forty-seven homebuilders who had built at least two homes in Massachusetts between 2004 and 2011 completed an extensive on-line survey between November 27, 2012 and March 4, 2013. Most respondents (116) had built at least one home through the Program; 31 respondents had not built any homes through the Program. The main goal of the survey was to understand the factors influencing changes in building practices. The survey asked builders about changes in their building practices between 2004 and 2011 in the following seven areas:

- Insulation
- Types and/or efficiency levels of HVAC systems installed
- Types and/or efficiency levels of water heating systems installed
- Installation, insulation, or testing of ducts
- How air infiltration is addressed
- Portion of sockets with energy-efficient lighting
- Efficiency level of windows

The survey asked builders to provide attribution scores for factors affecting the changes in their building practices, including but not limited to the Massachusetts Residential New Construction Program, training, changing building codes, subcontractor and supplier availability, and customer demand. The respondents provided attribution scores for homes built through the Program, homes built outside the Program by builders who also built homes through the Program, and homes built by nonparticipant builders. In addition, builders were asked to assess changes they made in their building practices in order to participate in the Program. The complete report, *Massachusetts Residential New Construction Net Impacts Builder Survey Report*, is found in Appendix A.

The homebuilder survey was designed to be one of several inputs to be considered by the Delphi panel, described in Section 3, which had the ultimate responsibility of estimating the energy efficiency values that would have existed in 2011 in the absence of the Program which would be used to model energy saving attributable to the Program. While the homebuilders and the Delphi panelists, many of whom work as HERS raters, bring unique insights in assessing what energy efficient materials and practices are used, there are several reasons NMR considered the Delphi panelists responses to be more accurate.

- HERS raters work with homes constructed by different companies while builders are more knowledgeable about the materials and practices used in the homes constructed by their own companies. Thus, the HERS raters have a more accurate perspective on the Massachusetts residential new construction market as a whole.
- Subcontractors, rather than builders, are the decision makers for some energy efficient materials and practices. Again, HERS raters, who assess the energy efficiency of the house as a whole, are more likely to be aware of how these features have changed.

- HERS raters as well the other Delphi panelists, including residential new construction program managers in other states and program evaluation experts, have more knowledge of how residential new construction programs operate and the effect they have on the marketplace. Participating builders know of the incentives provided by the Program and their influence on their own practices, but have less knowledge of other activities such as training and working with code officials.

2.1 Attribution Scores

As shown in Table 2-1, homebuilders' attribution of changes in building practices to the Program is quite low, ranging from 30% for the portion of sockets in homes that have energy-efficient lighting installed in program homes to 2% for insulation, HVAC systems, and addressing air infiltration in homes built by nonparticipants.

Table 2-1: Mean Impact of Program Factor Effect on Changing Building Practices

(all respondents with changes to building practices between 2004 and 2011; percent (*sample size)*)

	Participants				Nonparticipants	
	Program Homes		Non-program Homes			
Mean Impact	**Mean Impact Weighted by builders**	**Mean Impact Weighted by program units**	**Mean Impact Weighted by builders**	**Mean Impact Weighted by non-program units**	**Mean Impact Weighted by builders**	**Mean Impact Weighted by units**
Insulation	17% (*102*)	18% (*6,157*)	7% (*44*)	5% (*1,362*)	2% (*29*)	1% (*708*)
Types and/or efficiency levels of HVAC systems	17% (*93*)	24% (*5,404*)	8% (*39*)	4% (*1,378*)	2% (*25*)	1% (*565*)
Types and/or efficiency levels of water heating systems	19% (*85*)	23% (*5,326*)	9% (*26*)	6% (*1,016*)	3% (*23*)	1% (*522*)
How ducts are installed, insulated, or tested	18% (*85*)	25% (*4,439*)	8% (*32*)	2% (*1,030*)	6% (*20*)	3% (*483*)
Addressing air infiltration	20% (*71*)	28% (*3,852*)	9% (*31*)	3% (*1,051*)	2% (*24*)	<1% (*660*)
Portion of sockets in homes that have energy-efficient lighting installed	30% (*65*)	26% (*2,816*)	17% (*19*)	3% (*901*)	4% (*14*)	<1% (*212*)
Efficiency level of windows installed	20% (*57*)	34% (*2,872*)	6% (*22*)	1% (*820*)	2% (*22*)	1% (*333*)

As already noted, homebuilders have a more narrow perspective on the Program's influence than the Delphi panelists who provided the energy efficiency values used to model savings attributable to the Program. In addition to the factors already listed, when reviewing the rather low attribution percentages provided by homebuilders, it is important to consider that they may have been understated for two additional reasons. First, the respondents have attributed changes in HVAC and water heating measures to the adoption of the IECC 2009 code even though the IECC 2009 code does not have any prescriptive requirements for heating, cooling or water heating system efficiencies other than needing to meet federal minimum efficiency. (Minimum standards for heating systems did not change between 2004 and 2011, though requirements became more efficient for water heating and central air conditioning systems.) This may reflect a tendency to attribute any change to “code” without considering the measures in question. Second, many of the factors receiving higher attribution percentages are likely due, at least in part, to the operation of the Program, in some form, since the early 1990’s. For example, the availability of HERS raters to work with builders and the adoption of the stretch code have been influenced by program efforts over the years.

2.2 Supporting Factors

While builders gave rather low attribution percentages to the Program for changes to their building practices, their feedback on changes to participating homes, training, changing building codes and enforcement, subcontractor and supplier availability, and customer demand indicates more Program influence on energy-efficient practices. This section notes some of the highlights of the builder survey; more extensive information and tables are found in Appendix A.

2.2.1 Participating Builder Perspectives

Most builders participating in the Program (86%) said they made some changes to their building practices in order to go through the Program; the areas most likely to be affected are air sealing, installation of energy-efficient lighting, insulation levels, and HVAC equipment efficiency. Moreover, three-fifths (60%) of participating builders who build homes outside the Program said that they use building designs, practices, equipment or measures in these homes as a result of their experiences building Program homes, indicating some participant spillover. Again, the areas most likely to be affected include air sealing, insulation levels, HVAC equipment efficiency, installation of energy-efficient lighting, water heater efficiency, and insulation of ducts in unconditioned spaces. Still, the vast majority of participating builder respondents who built homes outside the program (95%) reported that nonparticipating homes are different from participating homes, most commonly in the installation of energy-efficient lighting, air sealing, and insulation levels.

While most participants made some changes in order to go through the Program, fewer than one-half (46%) reported that they would discontinue practices if the program went away. The practices most likely to be discontinued include installation of energy-efficient lighting, water heater efficiency, and HVAC equipment efficiency.

Close to one-half (47%) of participating builders said there is some nonparticipant spillover; they said the program has a great or moderate impact on the practices of non-participating builders, particularly in the areas of insulation, air sealing, HVAC equipment efficiency, and insulation of ducts in unconditioned spaces.

2.2.2 Nonparticipating Builder Perspectives

Nonparticipating builder responses also indicate a strong probability of some spillover. Most (74%) nonparticipating builders knew of the Program; of those aware of the Program, more than one-half (57%) knew of someone who has participated in the Program, and most (77%) of those builders had discussed energy-efficient building designs, practices, equipment or measures with Program participants.

2.2.3 Training

Most respondents (73% of program participants and 68% of nonparticipants) said they have attended some training on energy-efficient building practices. Participants are most likely to have attended training sponsored by the Program; nonparticipants are most likely to have attended training sponsored by manufacturers or distributors and builder associations.

2.2.4 Codes and Enforcement

Most respondents have homes completed, under construction, or planned that were or will be covered by the stretch code. Program participants mainly (70%) looked to HERS raters and their own program experience for information on stretch code requirements. Nonparticipants were more likely to look to trainings sponsored by manufacturers/distributors (75%) or builder associations (44%).

Most respondents (88% of program participants and 90% of nonparticipants) said code officials are now more likely to at least check the energy efficiency measures installed than was the case several years ago; however, many also noted that checking and, particularly, enforcement varied by the city or town. Insulation levels, including ducts in unconditioned spaces, were most likely to be checked.

2.2.5 Subcontractors and Supplies

More than nine out of ten respondents said their subcontractors and suppliers have become much more or somewhat more knowledgeable of and willing to recommend energy-efficient equipment and installations over the past eight years. Most respondents also said the materials and equipment needed for energy-efficient construction have become much more or somewhat more readily available; a sizable minority (35% of program participants and 39% of nonparticipants) also said prices have become somewhat more reasonable.

2.2.6 Consumer Demand

Most respondents (82% of participants and 84% of nonparticipants) said that homebuyers are at least more likely to ask questions about a home's energy efficiency and/or heating and cooling costs now than in the past. Respondents also said that high energy prices have had the strongest influence on the higher interest in energy efficiency on the part of consumers. However, a sizable minority of respondents (32% of participants and 26% of nonparticipants) said the Program has had a significant or moderate influence on consumer demand for energy-efficient homes.

3 Delphi Panel Process

The Delphi method is often characterized as a group communication process or forecasting method that relies upon panels of experts to develop an estimate or group judgment. It is an interactive process that commonly involves two rounds of questions. The Delphi technique is based on the principle that structured responses from experts will be more accurate than unstructured response from individuals.

Data collection using the Delphi technique uses the following steps. First, panelists who are experts in the field or topic of interest are recruited to participate in the Delphi panel. Next, the panelists are presented with a topic or scenario, supporting data, and a questionnaire. The questionnaire typically includes both structured, or close-ended, questions and open-ended questions. The open-ended questions are used to solicit respondents' assumptions or the reasoning used to arrive at their responses to the close-ended questions of the survey. Next, the data, both quantitative and qualitative, are summarized and a second questionnaire is sent to the panelists. In the second questionnaire, respondents are asked to review the data summary and their own original responses, provide revisions to their original responses (if necessary), and provide their reasoning for revising (or retaining) their original responses.[2]

3.1 Delphi Panel Recruitment

NMR sought to recruit panelists with expertise in energy-efficient residential new construction (RNC), the Massachusetts RNC market, how RNC programs operate, and evaluation of programs promoting energy efficiency. NMR worked with the Massachusetts Program Administrators to identify twenty-three suitable panel candidates who were contacted via mail and telephone calls and invited to participate in the panel. Fourteen candidates agreed to participate; they were divided into four categories as shown in Table 3-1.

Table 3-1: Delphi Panelists

Category	Number of Panelists
Building efficiency consultants working in Massachusetts	8
Building efficiency consultants working outside Massachusetts	2
RNC program managers outside Massachusetts	2
Energy efficiency program evaluators working nationally	2

[2] See: (A) Hsu, C. and B.A. Sandford. (2007). ―The Delphi technique: making sense of consensus.‖ *Practical Assessment, Research & Evaluation*. 12(10): 1-8; (B) Linstone, H. A., & Turoff, M. (1975). *The Delphi Method: Techniques and Applications*. Reading, MA: Addison-Wesley Publishing Company; (C) Ludwig, B. (1997). ―Predicting the future: Have you considered using the Delphi methodology? *Journal of Extension*, 35 (5), 1-4. Retrieved August 25, 2010 from http://www.joe.org/joe/1997october/tt2.html.

Most panelists were classified as building efficiency consultants working in Massachusetts; this category includes HERS raters and other professionals who have worked closely with builders participating in the Program. (Employees of the Program Administrators or the Program implementation contractor were not recruited to avoid any bias issues.)

One panelist, an energy efficiency program evaluator working nationally, was unable to participate in the second and final questionnaire round, so his responses are not included in the findings presented in this report. His input was, however, included in the first-round responses presented to the panelists at the start of the second round.

3.2 Development of the Delphi Panel Questionnaire

The objective of the Delphi panel was to estimate the energy efficiency values that would have existed in 2011 in the absence of the Program—both for homes that had gone through the Program and those that had not participated. The Delphi panel questionnaire was thus designed to produce inputs to REM/Rate modeling of 100 program homes and 100 non-program homes, under the assumption that the Program had not existed in the 2004 to 2011 period. Since the panelists were instructed to assume the Program had not existed between 2004 and 2011, they were also provided with 2004 energy efficiency values for program and non-program homes as well as extensive documentation of the Program's activities between 2004 and 2011, as described in Section 3.2.2.

3.2.1 First-round Delphi Panel Questionnaire

In order to reflect program and non-program homes more accurately, panelists were presented with the actual values for program homes and 100 non-program homes that had participated in the 2011 Baseline,[3] divided into three buckets or tiers for each of the measures studied: the 25% most efficient homes, the 25% least efficient homes, and the 50% of homes in the midrange. The Delphi panel questionnaire included mean energy efficiency values for each of the three tiers for the following measures:

- Duct leakage (CFM25/100 ft^2)
- Air infiltration (ACH50)
- Lighting (percent saturation of energy-efficient lighting)
- Windows (U-values)
- Insulation presented separately for walls, flat ceilings, cathedral ceilings, frame floors over unconditioned space, and foundation walls. Both R-values and the percentage of the area with insulation installation Grades I, II, and III were presented for each of the five insulation measures.

[3] NMR Group Inc., KEMA Inc., The Cadmus Group Inc., and Dorothy Conant, *Massachusetts 2011 Baseline Study of Single-family Residential New Construction*, August 16, 2012

- Heating systems (AFUE values for gas/propane furnaces, gas/propane boilers, oil furnaces, and oil boilers)
- Central air conditioning (SEER values)
- Domestic water heating (energy factors for conventional gas storage, conventional electric storage, on-demand tankless instantaneous, and indirect fired water heaters)

Panelists provided both the mean energy efficiency values that would have existed in the absence of the Program for each tier and the percentage of the homes that would have fallen into each tier (the tiers had high and low value constraints) for both program and non-program homes. Additionally, each panelist provided a brief explanation of his or her reasoning for the estimated values. The questionnaire was provided to panelists as an Excel spreadsheet, which made it clear when the percentages of homes in the three tiers added to 100%; the spreadsheet did not allow mean values outside the specified range for each tier. An example of the first-round questions for duct leakage is shown in Table 3-2; the entire questionnaire is provided in Appendix B.1.1.

Table 3-2: First-Round Delphi Panel Questionnaire for Duct Leakage

Duct Leakage	Program Homes (single-family only) 2011 % of Homes	Duct Leakage	Percent of Homes in Each Tier In Absence of Program	Average Duct Leakage in Each Tier In Absence of Program	Duct Leakage	Non-Program Homes (single-family only) 2011 % of Homes	Duct Leakage	Percent of Homes in Each Tier In Absence of Program	Average Duct Leakage in Each Tier In Absence of Program
Average Duct Leakage (CFM25/100 ft^2 conditioned space)	100%	3.3			Average Duct Leakage (CFM25/100 ft^2 conditioned space)	100%	12.4		
Poor--High Duct Leakage Tier 4.6 to 8.5 CFM25/100 ft^2	25%	5.3			**Poor**--High Duct Leakage Tier 15.0 to 52.3 CFM25/100 ft^2	25%	25.0		
Mid Duct Leakage Tier 2.2 to 4.6 CFM25/100 ft^2	50%	3.3			Mid Duct Leakage Tier 6.7 to 14.7 CFM25/100 ft^2	50%	10.8		
Low Duct Leakage Tier 0.0 to 2.2 CFM25/100 ft^2	25%	1.3			Low Duct Leakage Tier 0.0 to 6.2 CFM25/100 ft^2	25%	3.4		
			0%					0%	

Please type an explanation of your reasoning behind duct leakage estimates in the space below:

3.2.2 Supporting Materials

The first-round Delphi panel questionnaires included extensive supporting materials documenting changes in building practices and codes between 2004 and 2011 and Program activities that may have influenced those changes. Most supporting materials were provided as part of the Excel spreadsheet that contained the first-round questionnaire and are provided in Appendix B.1.2. The spreadsheet had eight tabs, which are described briefly below:

- **Introduction and Questions** provided instructions for completing the study and the entire questionnaire.
- **Program Description** summarized the Program's purpose, history, and current incentives.
- **Building Practices and Codes** summarized building practices in program and non-program homes in 2004 and 2011 for all of the measures studied and the applicable building code requirements in the two years.
- **Requirements and Benefits** summarized the Program's changing requirements from 2004 through 2011, the benefits provided to builders and the energy efficiency of participating homes, measured by their HERS indices. Program benefits included subsidized HERS ratings and CFLs as well as monetary incentives.
- **Market Penetration** summarized the market share of new homes completed in Massachusetts that participated in the Program from 1998 through 2011, separately for single and multi-family homes.
- **Training** summarized training offered by the Program to homebuilders, subcontractors, HERS raters, and real estate agents from 2004 through 2011
- **Code Support** summarized the work done by the Program to promote the IECC 2009 building code and, particularly, the stretch code, including working with over 60 individual communities through the end of 2011 and providing training to builders and code officials.
- **Marketing** summarized the marketing done by the Program which may have affected building practices. This section documented Program booths and exhibitions in various building conferences which may have influenced nonparticipating builders.

In addition to the supporting materials summarized above, the Delphi panelists received a 23-page summary of the homebuilder survey described in Section 2, with the option to request the entire report.

3.2.3 Second-round Delphi Panel Questionnaire

The second-round Delphi panel questionnaires were also provided as Excel spreadsheets, customized for each panelist. The spreadsheets had twelve tabs, one for each measure.[4] For each

[4] The five insulation measures—walls, flat ceilings, cathedral ceilings, frame floors, and foundation walls—each had a separate tab.

measure, the questionnaires summarized the energy efficiency values estimated from the first round, providing the mean and the range of values from lowest to highest. Panelists could also request the entire data set of the first-round responses (stripped of the respondent names) in order to examine distributions or calculate any other statistics. The spreadsheet also provided each panelist's responses directly below the first-round response ranges and means. Panelists filled in their second-round responses below their first-round responses and, again, provided their reasoning for either changing or not changing their responses from the first round. Table 3-3 shows an example of the second-round questionnaire for duct leakage.

Table 3-3: Second-round Delphi Panel Questionnaire for Duct Leakage

	Program Homes (single-family only)					Non-Program Homes (single-family only)			
	2011					2011			
Duct Leakage	% of Homes	Duct Leakage	Percent of Homes in Each Tier In Absence of Program	Average Duct Leakage in Each Tier In Absence of Program	**Duct Leakage**	% of Homes	Duct Leakage	Percent of Homes in Each Tier In Absence of Program	Average Duct Leakage in Each Tier In Absence of Program
Average Duct Leakage (CFM25/100 ft^2 conditioned space)	100%	3.3			Average Duct Leakage (CFM25/100 ft^2 conditioned space)	100%	12.4		
Total Percentage of Homes (must equal 100%)			0%					0%	
Poor--High Duct Leakage Tier 4.6 or higher CFM25/100 ft^2					**Poor--High Duct Leakage Tier 15.0 or higher CFM25/100 ft^2**				
Actual	25%	5.3			**Actual**	25%	25.0		
Panelists' Round 1 Responses			Low 40% Mean 71.1% High 100%	Low 5.0 Mean 10.9 High 25.0	**Panelists' Round 1 Responses**			Low 5% Mean 46.4% High 75%	Low 15.0 Mean 25.1 High 35.0
Your Response (First Round)			xx%	x.x	Your Response (First Round)			xx%	x.x
Your Response (Second Round)					*Your Response (Second Round)*				
Mid Duct Leakage Tier 2.2 to 4.6 CFM25/100 ft^2					**Mid Duct Leakage Tier 6.7 to 14.7 CFM25/100 ft^2**				
Actual	50%	3.3			**Actual**	50%	10.8		
Panelists' Round 1 Responses			Low 0% Mean 21.4% High 40%	Low 4.0 Mean 4.3 High 4.6	**Panelists' Round 1 Responses**			Low 20% Mean 43.8% High 90%	Low 4.7 Mean 10.9 High 14.0
Your Response (First Round)			xx%	x.x	Your Response (First Round)			xx%	x.x
Your Response (Second Round)					Your Response (Second Round)				
Low Duct Leakage Tier 0.0 to 2.2 CFM25/100 ft^2					**Low Duct Leakage Tier 0.0 to 6.2 CFM25/100 ft^2**				
Actual	25%	1.3			**Actual**	25%	3.4		
Panelists' Round 1 Responses			Low 0% Mean 7.6% High 20%	Low 1.0 Mean 1.9 High 2.2	**Panelists' Round 1 Responses**			Low 0% Mean 9.8% High 20%	Low 0.0 Mean 4.7 High 6.0
Your Response (First Round)			xx%	x.x	Your Response (First Round)			xx%	x.x
Your Response (Second Round)					Your Response (Second Round)				

Please explain why you changed or did not change your duct leakage estimates in the space below:

In addition to the energy efficiency variables calculated from the first-round responses, the second-round questionnaire provided the verbatim comments from the first round explaining the reasoning behind each estimate, identified by the panelists categories listed in Table 3-1. The complete second round materials are provided in Appendix B.2.

4 Delphi Panel Findings

Once the thirteen panelists had completed the second-round questionnaires, data analysis consisted of identifying and removing outlier responses and calculating the mean energy efficiency values that would have existed in 2011 in the absence of the Program.

4.1 Data Analysis

The first step in Delphi panel data analysis is identifying outlier responses. As noted in Section 3.2.1, the panelists had estimated energy efficiency values for three tiers as well as the percentage of homes falling into each tier. The data analysis began by developing weighted average energy efficiency values for the various measures and comparing responses from the thirteen panelists. Outliers were defined as greater than 1.5 times the interquartile range. In addition to outliers, a small number of responses (no more than three for any given measure) did not appear to be reasonable; for example, if a respondent estimated that the weighted average energy efficiency value for program homes would be lower than that for non-program homes. In these cases, panelists were contacted and asked if they had indeed meant for this to be the case. The majority said they had not; their responses for that particular measure were then deleted from the data analysis. The numbers of responses deleted for various measures are found in Appendix B.3. Once the data cleaning was completed, mean energy efficiency values were calculated for each tier for all the measures studied.

4.2 Findings

Table 4-1compares the mean energy efficiency values calculated after cleaning the Delphi panel responses, as weighted averages of the values estimated for each tier and the percentage of homes in that tier, to the actual values from the Program database and the Baseline Study. The REM/Rate modeling, as described in Section 5, used the percentage of homes in different tiers and the mean values for each tier as inputs. Appendix B.3 provides the data, by tier, used for the modeling.

Table 4-1: Energy Efficiency Values Estimated by Delphi Panelists

	Counterfactual—Values Estimated in the Absence of the Program		Actual Values from the Program Database and Baseline Study	
Energy Efficiency Value	**Program Homes**	**Non-program Homes**	**Program Homes**	**Non-program Homes**
Duct Leakage (CFM25/100 ft^2)	8.1	17.5	3.3	12.4
Air Infiltration (ACH50)	5.2	6.7	3.7	4.8
Lighting (percent saturation of energy-efficient lighting)	54%	10%	94%	20%
Windows (U-value)	0.32	0.34	0.31	0.34
Insulation:				
Wall insulation R-value	17.6	16.9	19.5	19.4
Flat ceiling insulation R-value	36.2	32.3	40.9	36.8
Cathedral ceiling insulation R-value	33.5	31.4	36.3	35.5
Frame floor insulation R-value	23.7	22.1	27.1	26.7
Foundation wall insulation R-value	11.4	10.1	13.7	12.7
Heating Systems:				
Gas furnace AFUE	90.9%	89.0%	92.8%	92.0%
Gas boiler AFUE	90.9%	88.0%	93.4%	89.8%
Oil furnace AFUE	83.5%	82.3%	85.7%	82.7%
Oil boiler AFUE	84.2%	83.7%	85.2%	85.9%
Central Air Conditioning SEER	13.4	13.2	13.6	13.6
Domestic Hot Water Systems:				
Conventional gas storage energy factor	0.63	0.61	0.63	0.63
Conventional electric storage energy factor	0.90	0.88	0.91	0.89
On-demand (tankless) instantaneous gas energy factor	0.84	0.83	0.87	0.83

As shown in Table 4-1, counterfactual values for some measures are quite different from the observed values for both program and non-program homes. For other measures, the Delphi panelists said efficiency would have been relatively unaffected by the absence of the Program. It should also be noted that the Delphi panelists said that, for a considerable number of measures, the Program had significant effects on nonparticipant homes. One panelist noted:

> *The goal of this study is to develop net-to-gross estimates for the ESH Program. That is, what would have happened to building practices associated with P (participant) and NP (non-participant) homes, absent the program from 2004-2011. At first review, the program is apparently having an impact in many building practices since the P homes are significantly more efficient than the NP homes in many areas such as, duct leakage, air infiltration, lighting, insulation quality, etc.… I conclude it's extremely likely the program has raised the NP baseline (spillover), more or less, with each specific building practice… for several reasons.*
>
> - *Builders generally don't build homes -- subcontractors do.*
> - *Subcontractors generally follow the same practices for all homes, for example, they don't install insulation sloppily on one project, and then meticulously on the next.*
> - *Program longevity is high, since 1991.*
> - *Program components are many, including training, marketing, code support and incentives.*
> - *The program had special training elements targeted at the trades, such as quality insulation installation.*
>
> *For these reasons, a raised NP baseline plays a key role in my assessments of the individual building practices, especially when they are tied to subcontractor skill/training, such as insulation installation or duct sealing. In contrast, building practices that are more closely tied to home design or equipment efficiency selection, are almost exclusively determined by the builder, and are more likely to be varied on a project-by-project basis.*
>
> *A raised NP baseline can result in net savings greater than the gross savings, and therefore NTG > 1.0 is possible. The evaluators need to carefully assess changes in the NP baseline as these savings can be many times the program participant savings especially when penetration rates are low. (Energy efficiency program evaluator working nationally)*

Examples of additional panelists' comments that provide some insight into their reasoning for the values assigned to specific measures are provided in the remainder of this section.

4.2.1 Duct Leakage

The Delphi panelists said duct leakage would have been more than twice as high for program homes and over 40% higher for non-program homes in the absence of the Program. Duct leakage is an area where many panelists consider the Program to have had a major impact. One panelist noted:

> *This is a good example where the program appears to have had a significant effect on building practices affecting P homes, and very likely raised the baseline of NP homes due to program training. Without the program incentives and training probably very few homes would have all ducts within conditioned spaces nor sealed to the measured levels, which requires higher quality workmanship. (Energy efficiency program evaluator working nationally)*

The mean duct leakage for both program and non-program homes in the absence of the Program exceeds the newly adopted code requirements of 8 CFM25 per 100 square feet. Several panelists acknowledged this and noted that poor code enforcement meant that a large number of homes would not meet code in this area.

> *In the absence of the Program we would not have a base of HERS Raters qualified to do duct testing for code. And I expect this code requirement would have been rarely enforced if HERS Raters were not already operating in the marketplace and able to deliver this service. So my estimates above are…expected if the ducts were not being tested for code. This is based on our experience with HVAC Contractors being tested for the first time who were also unaware of the requirement for testing. (Building efficiency consultant working in Massachusetts)*

> *Many Building Inspectors do not require duct testing. Without the ESH duct requirements many of the builders and HVAC subs would not make the extra [effort] to reduce duct leakage. (Building efficiency consultant working in Massachusetts)*

One panelist also noted that he had estimated significant duct leakage in the absence of the Program despite the responses from the Homebuilder Survey attributing most of the change in duct leakage to code changes:

> *The code requirement influence for ducts was reported as one of the largest among all the responses in the builder survey, which is supported by the fact that duct leakage requirements and testing actually represented a dramatic shift in the code requirements. I would also expect that because of the code change, and the time lag between implementation and enforcement, that over the next few years the difference between what would have happened in a non-program market environment and what is actually happening will shrink, and that more builders will choose to push ducts inside (to avoid the need to test). But that doesn't mean*

> *the difference will disappear, of course—towns will never enforce the code equally, and non-program testers are less likely to be stringent in their testing procedures. (Energy efficiency program evaluator working nationally)*

4.2.2 Air Infiltration

The Delphi panelists said air infiltration would have been about 40% higher in both program and non-program homes in the absence of the Program, though still within the current code requirements. Again, panelists noted the availability of HERS raters underlying much of the improvement in air sealing practices.

> *Without enforcement of air sealing details by a HERS rater and without the planning for blower door testing and feedback from previous blower door tests, many air sealing requirements of code will be ignored by insulation contractors, builders and code enforcement. So in absence of the Program, I expect the infiltration performance of homes would be much worse. (Building efficiency consultant working in Massachusetts)*

> *Air infiltration/exfiltration had not been well understood by the building community before education, training, and testing were introduced through the ESH Program. Both participating and non-participating builders benefited…by the air-sealing promotion by the ESH program. (Building efficiency consultant working in Massachusetts)*

> *Programs like ESH, which have made blower door testing so much more common and well known throughout the industry, have had a big impact on ALL homes air tightness performance. (Building efficiency consultant working outside Massachusetts)*

4.2.3 Lighting

The Delphi panelists said energy-efficient lighting saturation would be less than 60% of its current value in program homes and one-half its current value in non-program homes in the absence of the Program. Panelists said these lower values would be due to the higher cost of CFLs and some customers' dislike of them. One panelist notes:

> *Without free CFLs from the Program plus the mandatory Program requirement to install at least 80% CFL's, the builder will choose the lowest cost bulbs and/or the bulbs with the most acceptable aesthetics (often clear incandescent bulbs or halogen bulbs). In my experience, code enforcement rarely pays attention to the 50% high efficacy prescriptive requirement in the 2009 IECC. The majority of builders would use the default bulbs provided by their electricians unless the program was requiring them install the free CFL's. (Building efficiency consultant working in Massachusetts)*

4.2.4 Windows

The Delphi panelists said windows in program homes would have average U-values of 0.32 rather than 0.31 while non-program home windows would remain at 0.34 in the absence of the Program. The panelists generally did not believe that the Program had a significant impact on windows; one noted:

> *Code has had a bigger impact on window selection than other requirements, probably because of standardization (NFRC labeling) and clarity of the requirements. National and local manufacturers have a strong incentive to insure that their windows will sell, and therefore mostly supply only code compliant products to a region. (Building efficiency consultant working in Massachusetts)*

4.2.5 Insulation

The Delphi panelists said that most insulation R-values would not be very different in the absence of the Program. The greatest R-value changes are for flat ceiling insulation where program homes go from an average of 40.9 to 36.2 and non-program homes go from 36.8 to 32.3. The smallest R-value changes are for wall insulation where program homes go from an average of 19.5 to 17.6 and non-program homes go from 19.4 to 16.9.

The Delphi panelists said, however, that insulation installation grades, which are already quite different for program and non-program homes, would be much poorer in the absence of the Program, especially for homes that would have participated in the Program. Grade I describes insulation that is generally installed according to manufacturer's instructions and/or industry standards. A Grade I installation requires that the insulation material uniformly fills each cavity side-to-side and top-to-bottom, without substantial gaps or voids around obstructions (such as blocking or bridging), and is split, installed, and/or fitted tightly around wiring and other services in the cavity. To attain a rating of "Grade I", wall insulation must be enclosed on all six sides, and in substantial contact with the sheathing material on at least one side (interior or exterior) of the cavity and generally not compressed.[5] As a practical matter, Grade I insulation requires blown in cellulose or spray foam; homes with only fiberglass batt insulation generally do not qualify for Grade I.

As shown in Table 4-2, the percentage of various areas with Grade I insulation decline dramatically in the absence of the Program; in the cases of wall, flat ceiling, cathedral ceiling, and frame floor insulation, Delphi panelists said the areas with Grade I insulation installation will decline by 60% or more. (More detailed Delphi panel responses for insulation installation grades are found in Table B-32 through Table B-36 in Appendix B.3.)

---

[5] Adapted from Residential Energy Services Network. (2006). *2006 Mortgage Industry National Home Energy Rating Systems Standards.* Oceanside, CA: Residential Energy Services Network.

Table 4-2: Grade I Insulation Installation

	Counterfactual—Values Estimated in the Absence of the Program		Actual Values from the Program Database and Baseline Study	
Area of Insulation	**Percent of Program Home Area**	**Percent of Non-program Home Area**	**Percent of Program Home Area**	**Percent of Non-program Home Area**
Wall insulation	21%	8%	65%	9%
Flat ceiling insulation	30%	16%	88%	37%
Cathedral ceiling insulation	32%	7%	88%	37%
Frame floor insulation	6%	0%	15%	0%
Foundation wall insulation	22%	6%	55%	20%

The panelists stressed the role of the subcontractors and training in maintaining insulation installation grades:

> *Insulation installation quality is ALWAYS a factor of subcontractor skill/training, and the insulation R-value is SOMETIMES driven by the sub (depending on type of insulation, e.g. blown in vs. batt). Program training, and program QA, very likely contributed to installers' practices. In absence the program, I would expect the baseline to get worse. I believe most trades work one way, they like to repeat performance on each job. Therefore, once trained to a higher level, they'll tend to use those methods on all jobs, regardless if the homes are P or NP. (Energy efficiency program evaluator working nationally)*

> *Though higher insulation levels are promoted by HERS Raters and ESH program, code levels of insulation have been increasing, and stretch code requirements are in effect in many areas. The incentives have an indirect relationship to insulation decisions in that unless there is an easy way to increase insulation (i.e., an attic flat with lots of room) the argument for doing more than just changing from fiberglass to better materials is a difficult one to make. The bigger impact the program has had is driving better installation practices and making builders aware that it's in their interest to make sure the insulation subs do the job right, rather than just fast. If the program were not in effect, insulation levels would likely not change much, but quality of installation would not be as good. (Building efficiency consultant working in Massachusetts)*

4.2.6 Heating Systems

The Delphi panelists said that heating system efficiency levels would be moderately different in the absence of the Program with gas furnace average AFUEs dropping from 92.8% to 90.9% for program homes and from 92.0% to 89.0% for non-program homes. Moreover, panelists said that, in the absence of the Program, more program homes (6%) would have oil systems compared to the actual value of 2% of program homes. One panelist noted:

> *I think the feedback given by HERS Raters with respect to qualifying for rebates pushes the efficiency of the equipment upwards and it also pushes the type of system toward natural gas equipment as opposed to oil equipment. So without the Program we would see more Oil equipment and more low efficiency equipment. (Building efficiency consultant working in Massachusetts)*

However, other panelists said the Program has had less impact on heating systems than on other measures:

> *Heating equipment decisions are largely made based on: what's available in the marketplace from manufacturers, the incentives they use with their distributors and subs, and relationships between builders and subcontractors….The program incentives have been effective in pushing higher efficiencies for gas-fired furnace equipment and boilers due to the small incremental cost and constant messaging about higher-efficiency, but I don't feel the percentages would have changed much absent the program. (Building efficiency consultant working in Massachusetts)*

4.2.7 Central Air Conditioning

The Delphi panelists said that the average central air conditioning SEER would have been slightly lower in the absence of the Program. One noted:

> *Despite program incentives, the HVAC industry is well entrenched and decisions are often driven by contractor relationships and equipment supplier incentives, rather than design team input. The program incentives are not substantial enough to make much of a difference in this environment. (Building efficiency consultant working in Massachusetts)*

Still, another panelist noted the influence of HERS raters:

> *I expect a lot of AC systems would be low efficiency without the extra attention given to them by HERS Raters. The best builders would still have put in more high efficiency systems but in most cases they would go with the lowest cost solution offered by the HVAC Contractor meaning SEER 13. (Building efficiency consultant working in Massachusetts)*

4.2.8 Domestic Hot Water Systems

The Delphi panelists said that the average energy factors for domestic hot water (DHW) systems would have been slightly lower, for most systems, in the absence of the Program. However, as shown on Table 4-3, the panelists also said that the mix of DHW systems installed in program homes would have been quite different in the absence of the Program with more homes installing conventional storage systems and fewer homes installing on demand (tankless) instantaneous systems.

Table 4-3: DHW Systems Installed

	Counterfactual—Values Estimated in the Absence of the Program		Actual Values from the Program Database and Baseline Study	
DHW System	**Percent of Program Homes**	**Percent of Non-program Homes**	**Percent of Program Homes**	**Percent of Non-program Homes**
Conventional Gas Storage	50%	54%	39%	51%
On Demand (Tankless) Instantaneous Gas	23%	10%	39%	13%
Conventional Electric Storage	12%	19%	6%	20%
Indirect Fired (All Fuels)	15%	16%	15%	17%

One panelist explained the Program's effect on the mix of DHW systems:

> *The biggest program effect in DHW has been to switch builders from conventional technology to on-demand, or to try air-source heat pump DHW, primarily as a way to improve the HERS Score if the home performance is deficient in some other area. It's hard to say if there would be much change in this category since the stretch code is also driving these changes. Over the past program years, builders have been more incentivized to use indirect storage tanks when using a boiler, or even consider hydro-air systems to furnaces due to the performance benefit with a high performance boiler and combination of performance and monetary incentives, so this technology is familiar to builders. Had the program not been in effect, more conventional storage tank DHW would be used. (Building efficiency consultant working in Massachusetts)*

4.2.9 Massachusetts and non-Massachusetts Panelists

NMR ran several analyses examining the differences between the energy efficiency values estimated by the eight panelists with ties to the Massachusetts residential new construction market and the five panelists who work outside the state. The analyses sought to identify potential conflicts of interest on the part of the Massachusetts panelists; for example, if the Massachusetts panelists consistently estimated lower counterfactual efficiencies, the savings attributed to the Program and the net-to-gross value would be higher. NMR compared the mean counterfactual energy efficiency values found in Table 4-1 and Table 4-2 as well as the mean first-round and second-round responses for four measures that have a strong influence on modeled savings: duct leakage, air infiltration, lighting (for electricity) and flat roof insulation as estimated by Massachusetts and non-Massachusetts panelists. In all cases, the more efficient values were dispersed between the Massachusetts and non-Massachusetts panelists. Thus, the panelists do not appear to us to have any systematic bias. The analyses conducted are found in Appendix B.4.

5 Modeling Energy Consumption

In order to model the Delphi estimates of what would have happened in the absence of the Program, NMR began with a sample of non-program REM/Rate files, from the 2011 Baseline Study,[6] and a sample of program REM/Rate files from the 2011 program year. Specifically, NMR considered 74 single-family non-program homes and a random sample of 100 single-family program homes.[7] The original non-program sample consisted of 100 homes, but NMR excluded 26 homes from the full non-program sample as diagnostic testing at these 26 homes was not consistent with the 2011 program approach (more details on these 26 homes can be found in Appendix C).

For both samples (program and non-program homes), the original REM/Rate files can be considered the "as-built" files; the models for these homes contain all of the characteristics identified on-site during the auditing process. The as-built models were compared to two counterfactual models for both samples. The savings between the as-built models and the counterfactual models were used to calculate the net-to-gross ratio for the Program (more on this process can be found in Section 6).

5.1 Development of Counterfactual Efficiency Values

As discussed in Section 3.2, for each of the 12 efficiency measures considered by the Delphi panel, for both program and non-program homes, the panelists provided both the percentage of homes that would have fallen into each efficiency tier (high, medium, or low efficiency) and the mean efficiency values that would have existed in the absence of the Program. There were 13 panelists who completed both rounds of the Delphi panel (for both program and non-program homes); for all 12 measures considered by the panel, the panelists provided 13 estimates for the percentage of homes in each efficiency tier and 13 estimates of the corresponding mean efficiency value in each tier. This information allowed NMR to construct a counterfactual probability distribution of efficiency values within each tier. Counterfactual values were assigned as follows:

1. First, each home was randomly assigned to one of the three efficiency tiers based on the counterfactual average percentage of homes assigned to each tier. For example, the average estimated percentage of program homes with poor duct leakage (low efficiency) in the absence of the Program, across all 13 panelists, was 71.8%. Thus, NMR randomly assigned program homes to the low efficiency duct leakage tier with a probability of 0.718.
2. Once a home was assigned to a particular tier, an efficiency value was generated within that tier. Using the panelists' responses, NMR was able to construct a probability

[6] NMR Group Inc., KEMA Inc., The Cadmus Group Inc., and Dorothy Conant, *Massachusetts 2011 Baseline Study of Single-family Residential New Construction*, August 16, 2012
[7] The 2011 Program had 1,180 completed, non-code plus, single-family homes.

distribution of counterfactual efficiency values and then randomly select a value from that distribution. Consider the low efficiency duct leakage tier for program homes again. Each panelist provided their estimate of the *average* counterfactual duct leakage value in the low efficiency tier. The average of those estimates across all 13 panelists was 9.91 CFM25/100 ft^2 with a range of 6.0 to 15.0. Based on this information, NMR created a probability distribution whose mean was equal to 9.91, with a range of 6.0 to 15.0 and randomly selected a value from that distribution for each program home that had been randomly assigned to the low efficiency duct leakage tier. Each of those values then served as the mean of a normal distribution from which a final efficiency value was randomly drawn to represent each home's counterfactual duct leakage value. The distributions that NMR sampled from were constructed in such a way that no values beyond the upper and lower bounds for each tier were accepted as values for homes assigned to that tier.

3. This process was repeated for all tiers across all 12 efficiency measures for all program and non-program homes.

Steps 1 – 3 were carried out twice for program homes and twice for non-program homes in order to obtain the inputs necessary to run the two counterfactual models per home. The approach outlined above allowed NMR to account for the variability in the panelists' responses while also correctly modeling the average value within each tier.

5.2 Application of Counterfactual Efficiency Values

NMR created four counterfactual models, two each for program homes and non-program homes, which reflected the counterfactual values that were generated based on the Delphi estimates. NMR revised the as-built models by changing the inputs for the variables below in each of the four counterfactual model runs. Note that the Program uses deemed savings to calculate the savings attributable to energy-efficient lighting; as a result lighting was not included in the modeling and was calculated using the same methodology as the Program (see Section 5.2.2 for additional details).

- Duct leakage to the outside (CFM25/100 ft^2)
- Air infiltration (ACH50)
- Windows (U-value)
- Wall insulation—all locations abutting conditioned space
    - R-value
    - Installation grade
- Ceiling insulation—both flat and cathedral ceilings
    - R-value
    - Installation grade
- Frame floor insulation—all locations abutting conditioned space

  - R-value
  - Installation grade
- Foundation wall insulation—all locations abutting conditioned space
  - R-value
  - Installation grade
- Heating system AFUE
  - Gas furnace
  - Gas boiler
  - Oil furnace
  - Oil boiler
- Central air conditioning systems (SEER)
- Domestic hot water system
  - Conventional gas storage energy factor
  - Conventional electric storage energy factor
  - On-demand (tankless) instantaneous energy factor

All applicable values were changed for each counterfactual model. Modeling in this manner accounts for interactive effects between the various measures that were assessed by the Delphi panelists.

5.2.1 Calculating Net Savings

The modeled energy consumption values from the as-built models were subtracted from the energy consumption values of the counterfactual models to estimate savings realized by program and non-program homes. Specifically, the information from the two counterfactual runs was combined by averaging the modeled counterfactual consumptions for each home, providing a more robust estimate of each home's counterfactual energy consumption than a single run. The modeled energy consumption value from the as-built model was then subtracted from the average counterfactual consumption value to calculate net savings for each home. Averaging over all homes then yielded the average net savings, per home, for each sample of homes. This can be summarized more concisely by the following two equations:

$$counterfactual.energy.consumption_j = \frac{(run1.energy.consumption_j + run2.energy.consumption_j)}{2}$$

$$average.net.savings = \frac{1}{n}\sum_j (cf.energy.consumption_j - as.built.consumption_j)$$

Here, *j* indexes each home and *n* is the number of homes. This was done separately for program and non-program homes, which means *n* would be equal to 100 and 74, respectively. After calculating average net savings, 95% confidence intervals were constructed around the estimates to assess the statistical uncertainty.

5.2.2 Modeling Lighting

In order to maintain consistency with the program methodology for calculating savings, NMR calculated savings from energy-efficient light bulbs using the savings values listed in Table 5-1.[8]

Table 5-1: Lighting Savings per Bulb (kWh/yr)

CFL-Bulb Screw-In	Fluorescent Fixture Pin-Base	LED Fixture	Halogen Fixture
46.53	42.24	48	N/A

To calculate lighting savings for program homes, NMR was provided with the site-specific bulb counts for which savings were claimed in 2011. These counts were simply multiplied by the savings values in Table 5-1 to calculate the claimed lighting savings for program homes. The process for calculating lighting savings associated with the counterfactual runs was slightly more complicated. The Delphi panelists were asked to estimate what the saturation of energy-efficient light bulbs would have been in the absence of the program. Given this, the generated lighting values for the counterfactual models were saturation estimates. In order to calculate the savings from lighting, counterfactual bulb estimates were needed. Counterfactual bulb estimates were calculated by extracting the baseline efficient lighting saturation from the as-built REM/Rate models and comparing these saturation estimates to the counterfactual estimates. Using these data NMR was able to proportionately alter the number of energy-efficient bulbs to reflect the new counterfactual saturation estimates.[9] Table 5-2 presents an example of this process.

Table 5-2: Example of Counterfactual Bulb Count Estimates

Model Run	% Efficient Lighting	Counterfactual Count=(Counterfactual Saturation/Baseline Saturation)*Baseline Bulb Count				
		Total Bulbs*	# of Fluorescent Bulbs	# of LED Bulbs	# of Halogen Bulbs	# of CFL Bulbs
Baseline	91%	49.5	3	0	4	38
Counterfactual	39%	49.5	1.3	0	1.7	16.3

*NMR did not have counts of non-efficient bulbs and as a result had to estimate this value based on the efficient lighting saturation. As a result, the total bulb count was a fraction in most cases.

For non-program homes, NMR began with fixture counts, not bulb counts. During the 2011 baseline study it was decided to collect fixture information as that is what is required to populate a REM/Rate model. In order to convert fixture counts to bulb counts a multiplier of 1.49 was

[8] Sara DeCotis (ICF), email message to NMR, September 30th, 2013.
[9] NMR was unable to calculate counterfactual lighting savings for 3 of the 100 program homes. These homes had no efficient bulbs installed through the program and as a result had zero claimed lighting savings. These homes were assumed to have zero counterfactual savings as well. Two additional homes had efficient bulbs installed through the program, and as a result NMR calculated claimed savings, but these homes had inaccurate energy efficient saturation values in the REM/Rate files. In order to calculate realistic counterfactual savings estimates, NMR assumed that these homes met the program requirement of 80% energy efficient bulb saturations.

applied to the fixture counts for each site—NMR understands this to be consistent with program reporting efforts.[10] The bulb counts resulting from these calculations were then multiplied by the savings values in Table 5-1 to estimate the baseline lighting savings for non-program homes. The same process described above for counterfactual program savings estimates was applied to non-program homes.

The calculated lighting savings associated with each counterfactual run were added to the modeled savings estimates to calculate the overall savings for each home.

[10] Matt Nelson (Northeast Utilities), email message to NMR, October 7th, 2013.

6 Program Savings

This section presents the results of the modeling effort discussed in Section 5.

6.1 Calculating Claimed Program Savings

Each of the 100 program homes was compared to a user-defined reference home (UDRH) in REM/Rate to estimate the claimed savings for single-family homes from the 2011 program. Note that the program did not use REM/Rate, but rather used Beacon modeling software,[11] developed by the program implementation contractor, to calculate savings in 2011. That said, the program has decided to use REM/Rate to calculate program savings moving forward and as a result REM/Rate was used to estimate claimed savings as it is consistent with the approach that will be utilized by the program in the future.

A number of projects that began in 2010 were grandfathered into the 2011 program. These projects are considered legacy projects and were compared to the 2010 UDRH as that is how savings were claimed in 2011. The rest of the sample were strictly 2011 projects and were compared to the 2011 hybrid UDRH.[12]

Savings from efficient light bulbs were calculated using the deemed savings estimates listed in Table 5-1. Table 6-1 shows the estimated average claimed savings per home for the 2011 program.[13]

Table 6-1: Average per Home 2011 Claimed Savings Estimates

Confidence Interval*	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Fuel Oil (Gallons)	Propane (Gallons)
n	*100*	*100*	*81*	*3*	*14*
Low CI	46.4	2,632.7	325.0	81.9	358.8
Mid-Point	53.2	3,374.4	393.7	130.3	750.4
High CI	63.4	4,116.1	462.3	168.7	1,141.9

*95% confidence interval

[11] http://www.icfi.com/insights/products-and-tools/beacon
[12] Greg Krantz (ICF), email message to NMR, October 1st, 2013.
[13] The sample sizes for all fuel types except electricity do not add to the total sample, since the fuels have multiple uses. Two program homes use electricity for heating. Non-program homes used gas and propane for water heating and other uses, making the sum of the natural gas, fuel oil, and propane samples greater than the overall sample.

After calculating the average savings per home, NMR projected savings to the rest of the single-family projects that went through the program in 2011. In total, there were 1,180 single-family projects completed in the 2011 Program.[14,15] Table 6-2 presents the total number of single-family projects with each type of claimed energy savings in the 2011 program.

Table 6-2: Fuel Use Distribution for 2011 Single-Family Homes

Use Fuel	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Fuel Oil (Gallons)	Propane (Gallons)
n	*1,180*	*1,180*	*1,180*	*1,180*	*1,180*
Yes	1,180	1,180	966	42	165
No	0	0	214	1,138	1,015
% Using Fuel	100%	100%	82%	4%	14%

The per-home claimed savings estimates presented in Table 6-1 were multiplied by the number of homes using each fuel type in Table 6-2 to estimate the overall claimed savings for single-family homes in the 2011 program (Table 6-3).

Table 6-3: Total Estimated Claimed Savings for Single-Family Homes in 2011 Program Year

Confidence Interval*	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Fuel Oil (Gallons)	Propane (Gallons)
n	*1,180*	*1,180*	*966*	*42*	*165*
Low CI	54,752	3,106,586	313,950	3,440	59,202
Mid-Point	62,776	3,981,792	380,314	5,473	123,816
High CI	74,812	4,856,998	446,582	7,085	188,414

*95% confidence interval

6.2 Counterfactual Program Savings Estimates

As discussed in Section 5, NMR used Delphi responses to model energy consumption in the absence of the Program and calculate savings attributable to the Program. The difference between counterfactual energy consumption and as-built energy consumption for program homes are considered to be the net savings attributable to program participation. Table 6-4 displays a summary of the average per home as-built modeled energy consumption, counterfactual energy consumption, and net savings for program participants.

[14] Dorothy Conant, email message to NMR, October 11th, 2013.
[15] This value excludes code-plus projects. Including code-plus homes increases the number of single-family projects to 1,196.

Table 6-4: Summary of Average per-Home Program Participant Net Savings

Confidence Interval*	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Fuel Oil (Gallons)	Propane (Gallons)
n	*100*	*100*	*81*	*3*	*14*
As-Built Energy Consumption					
Low CI	89.56	7,110	629.66	365.67	672.98
Mid-Point	97.93	7,911	697.77	428.38	883.28
High CI	106.29	8,712	765.88	465.52	1,093.58
Counterfactual Energy Consumption					
Low CI	107.27	7,406	772.77	409.37	919.21
Mid-Point	119.84	8,160	881.12	489.67	1,343.14
High CI	132.41	8,914	989.47	542.52	1,767.07
Net Savings-Program Homes					
Low CI	19.30	1,000.72	130.05	14.61	191.15
Mid-Point	25.21**	1,273.39**	183.36	61.29	459.87
High CI	31.93	1,546.07	236.67	98.28	728.58

*95% confidence interval

**Note that the net savings for overall energy consumption and electric consumption are not equal to the difference between the counterfactual consumption and the as-built consumption presented above. This is because the net savings for these measures also included lighting savings. Lighting savings were equal to 1024.20 kWh per home; 95% CI = (836.08, 1212.31). This is equal to 3.30 MMBtu per home; 95% CI = (2.68, 3.89).

Table 6-5 displays the overall as-built energy consumption, counterfactual energy consumption, and net savings attributable to the Program for program participants. The savings were calculated by multiplying the consumption and savings estimates in Table 6-4 by the fuel-specific program distributions presented in Table 6-2.

Table 6-5: Total Program Participant Net Savings

Confidence Interval*	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Fuel Oil (Gallons)	Propane (Gallons)
n	*1,180*	*1,180*	*966*	*42*	*165*
As-Built Energy Consumption					
Low CI	105,681	8,389,800	608,252	15,358	111,042
Mid-Point	115,557	9,334,980	674,046	17,992	145,741
High CI	125,422	10,280,160	739,840	19,552	180,441
Counterfactual Energy Consumption					
Low CI	126,579	8,739,080	746,496	17,194	151,670
Mid-Point	141,411	9,628,800	851,162	20,566	221,618
High CI	156,244	10,518,520	955,828	22,786	291,567
Net Savings-Program Homes					
Low CI	22,774	1,180,850	125,628	614	31,540
Mid-Point	29,748**	1,502,600**	177,126	2,574	75,879
High CI	37,677	1,824,363	228,623	4,128	120,216

*95% confidence

** Note that the net savings for overall energy consumption and electric consumption are not equal to the difference between the counterfactual consumption and the as-built consumption presented above. This is because the net savings for these measures also included lighting savings. Lighting savings were equal to 1024.20 kWh per home; 95% CI = (836.08, 1212.31). This is equal to 3.30 MMBtu per home; 95% CI = (2.68, 3.89).

6.3 Counterfactual Non-Program Savings Estimates

As was the case with program homes, net savings attributable to non-program homes were calculated by subtracting the as-built energy consumption estimates from the counterfactual energy consumption estimates. Table 6-6 presents the average per-home as-built energy consumption, counterfactual energy consumption, and net savings estimates for non-program homes.

Table 6-6: Summary of Average per-Home Non-Program Net Savings

Confidence Interval*	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Fuel Oil (Gallons)	Propane (Gallons)
n	*74*	*74*	*48*	*9*	*18*
As-Built Energy Consumption					
Low CI	104.43	8,731	777.84	425.11	477.21
Mid-Point	111.81	9,623	867.40	470.39	644.80
High CI	119.20	10,515	956.96	515.68	812.39
Counterfactual Energy Consumption					
Low CI	120.00	8,917	899.51	489.76	628.04
Mid-Point	129.39	9,949	1,014.06	597.55	859.32
High CI	138.78	10,981	1,128.62	705.33	1,090.60
Net Savings-Non-Program Homes					
Low CI	13.38	325.05	83.54	41.12	91.73
Mid-Point	18.81**	686.85**	146.67	127.15	214.52
High CI	24.67	1048.64	209.79	213.18	337.31

*95% confidence

** Note that the net savings for overall energy consumption and electric consumption are not equal to the difference between the counterfactual consumption and the as-built consumption presented above. This is because the net savings for these measures also included lighting savings. Lighting savings were equal to 361.23 kWh per home; 95% CI = (99.57, 622.89). This is equal to 1.23 MMBtu per home; 95% CI = (0.34, 2.13).

6.3.1 Estimating Total Non-Program Net Savings

In order to estimate the total net savings attributable to all non-program homes in the state NMR projected the average per-home savings estimates to the estimated number of non-program single-family new construction completions in 2011. The number of completed single-family units was estimated using Census Bureau residential new construction building permit and Quarterly Starts and Completions reports.[16] Table 6-7 presents a summary of the numbers of single-family housing units completed (both program and non-program) in 2011.

Table 6-7: Estimated Statewide Single-Family Completions in 2011

Year	Estimated MA Single-Family Completions	Program Completions (Excludes Code Plus)	Estimated Non-Participant Completions	Percent of Homes Participating in Program
2011	5,835	1,180	4,655	20.2%

[16] http://www.census.gov/construction/nrc/

Data on the number of homes utilizing the various fuel types is not available and as a result NMR assumes that the distribution of fuel types within the non-participant sample is reflective of all non-participant homes throughout the state.[17]

Table 6-8: Total Non-Participant Net Savings

Confidence Interval*	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Fuel Oil (Gallons)	Propane (Gallons)
*n***	*4,655*	*4,655*	*3,019*	*566*	*1,132*
As-Built Energy Consumption					
Low CI	486,122	40,642,805	2,348,299	240,612	540,202
Mid-Point	520,476	44,795,065	2,618,680	266,241	729,914
High CI	554,876	48,947,325	2,889,062	291,875	919,626
Counterfactual Energy Consumption					
Low CI	558,600	41,508,635	2,715,621	277,204	710,941
Mid-Point	602,310	46,312,595	3,061,447	338,213	972,750
High CI	646,021	51,116,555	3,407,304	399,217	1,234,559
Net Savings-Non-Program Homes					
Low CI	62,284	1,513,108	252,207	23,274	103,838
Mid-Point	87,561***	3,197,287***	442,797	71,967	242,837
High CI	114,839	4,881,419	633,356	120,660	381,835

*95% confidence
**Fuel specific sample sizes are based on the distribution of each fuel type in the non-program sample and scaled up to reflect the overall non-program population.
*** Note that the net savings for overall energy consumption and electric consumption are not equal to the difference between the counterfactual consumption and the as-built consumption presented above. This is because the net savings for these measures also included lighting savings. Lighting savings were equal to 361.23 kWh per home; 95% CI = (99.57, 622.89). This is equal to 1.23 MMBtu per home; 95% CI = (0.34, 2.13).

6.4 Overall Net Savings and Net-to-Gross Ratios

Overall net savings were calculated by combining the counterfactual net savings of both program and non-program homes (Table 6-5 and Table 6-8). As shown, the net savings of the single-

[17] NMR investigated using census data for primary heating fuel as a means of projecting the average per home savings from the non-participant sample to the overall non-participant population. In order to do this, the sample of 74 non-participant homes would need to be broken down into the following categories: electricity as a primary heating fuel, electricity as a non-heating end use, natural gas as a primary heating fuel, natural gas as a non-heating end use, propane as a primary heating fuel, propane as a non-heating end use, and fuel oil as a primary heating fuel. Unfortunately, when breaking the homes down into these subcategories, the sample sizes were very small for certain categories. Specifically, homes with electricity as a primary heating fuel (sample size of two), homes with propane as a non-heating end use (sample size of three), and homes with natural gas as a non-heating end use (sample size of one) all had very low sample sizes. Ultimately, the Team determined that is was not appropriate to use the savings results from such a small sample of homes to estimate the savings for the overall population. As a result, the Team assumes that the distribution of fuel types within the non-participant sample is reflective of all non-participant homes throughout the state.

family program homes are estimated to be approximately 117,000 MMBtu, 4.5 million kWh, 620,000 therms, 74,500 gallons of oil, and 315,000 gallons of propane (Table 6-9).

Table 6-9: Overall Net Savings for 2011 Single-Family Homes*

Confidence Interval	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Fuel Oil (Gallons)	Propane (Gallons)
n	*5,835*	*5,835*	*3,985*	*608*	*1,297*
Low CI	89,836	3,013,393	427,417	33,066	183,466
Mid-Point	117,306	4,699,887	619,904	74,542	318,715
High CI	144,777	6,386,382	812,391	116,017	453,963

*Due to rounding error, some of the mid-points presented in this table do not compute exactly when adding the mid-points of counterfactual program and counterfactual non-program savings in Table 6-10.

Net-to-Gross ratios were calculated by comparing the combined net savings of program and non-program homes to the estimated savings claimed for the 2011 program year.

Overall, the program has a net-to-gross ratio of 1.87 (free ridership of 0.53 and non-participant spillover of 1.39) when assessing savings using the fuel neutral metric of MMBtu. When assessing electric and natural gas savings separately, the net-to-gross ratios for the program are 1.18 (free ridership of 0.62 and non-participant spillover of 0.80) and 1.63 (free ridership of 0.53 and non-participant spillover of 1.16), respectively. The higher overall net-to-gross ratio is due to the very high ratios calculated for homes using propane and, especially, fuel oil. [18]

Table 6-10 (on the next page) presents overall savings estimates (both claimed and counterfactual), estimated free ridership, non-participant spillover, and net-to-gross ratios for the program. The following algorithms were used to calculate free ridership, non-participant spillover, and net-to-gross:

$$Free\ Ridership = \frac{(Claimed\ Program\ Savings - Counterfactual\ Program\ Savings)}{Claimed\ Program\ Savings}$$

$$Non.Participant\ Spillover = \frac{Counterfactual\ NonProgram\ Savings}{Claimed\ Program\ Savings}$$

$$Net.to.Gross\ Ratio = 1 - Free\ Ridership + Non.Participant\ Spillover$$

[18] High net-to-gross ratios for homes using propane and fuel oil are due to the fact their program participation rate is very low. This means that their nonparticipant spillover is divided by a very small amount of claimed savings.

Table 6-10: Net Savings and Net-to-Gross Ratios

Confidence Interval	Overall (MMBtu)	Electricity (kWh)	Natural Gas (Therms)	Fuel Oil (Gallons)	Propane (Gallons)
Number of homes (Program/Non-Program)	*1,180/4,465*	*1,180/4,465*	*966/3,019*	*42/566*	*165/1,132*
Claimed Program Savings					
Low CI	54,752	3,106,586	313,950	3,440	59,202
Mid-Point	62,776	3,981,792	380,314	5,473	123,816
High CI	74,812	4,856,998	446,582	7,085	188,414
Counterfactual Program Savings					
Low CI	22,774	1,180,850	125,628	614	31,540
Mid-Point	29,748	1,502,600	177,126	2,574	75,879
High CI	37,677	1,824,363	228,623	4,128	120,216
Counterfactual Non-Program Savings					
Low CI	62,284	1,513,108	252,207	23,274	103,838
Mid-Point	87,561	3,197,287	442,797	71,967	242,837
High CI	114,839	4,881,419	633,356	120,660	381,835
Free Ridership					
Low CI	0.38	0.51	0.38	0.00	0.00
Mid-Point	0.53	0.62	0.53	0.53	0.39
High CI	0.67	0.74	0.69	0.88	0.82
Non-Participant Spillover					
Low CI	0.92	0.38	0.64	5.52	0.56
Mid-Point	1.39	0.80	1.16	13.15	1.96
High CI	1.87	1.23	1.69	25.35	3.36
Net-to-Gross					
Low CI	1.37	0.74	1.08	5.94	1.11
Mid-Point	1.87*	1.18	1.63	13.62	2.57
High CI	2.36	1.62	2.18	25.76	4.04

*Due to rounding error this does not compute exactly when using the net-to-gross formula of $1 - Free\ Ridership + Non.Participant\ Spillover$ equation.

7 Conclusions and Recommendations

The study found substantial net savings for the single-family component of the Massachusetts Residential New Construction Program. The Delphi panel estimated that, if the Program had not existed between 2004 and 2011, homes completed in 2011 would have been quite a bit less efficient—both those that would have participated in the Program and those that would not have participated. Combining a free ridership of 0.53 and non-participant spillover of 1.39 gives the program a net-to-gross ratio of 1.87 when assessing savings using the fuel neutral metric of MMBtu. This relatively high net-to-gross ratio is in line with findings from similar studies; in particular NMR examined net–to-gross ratios for California, New York, and Arizona.

The California study, which used a Delphi panel to determine the impact of RNC programs on previously identified market effects, had the highest net-to-gross ratio—6.25 for combined electric and gas savings. The high net-to-gross appears to be related to the long-term extensive training for builders, subcontractors, HERS raters, Title 24 consultants, and code officials provided by the RNC programs.[19] Furthermore, the California programs have a relatively low participation rate (12.1% in 2008)[20] allowing for a large quantity of spillover savings.

The New York ENERGY STAR® Labeled Homes (NYESLH) had a net-to-gross ratio of 1.17. This ratio was developed through interviews with participating and nonparticipating homebuilders and new home purchasers. The NYESLH evaluation also focused on one to four-family homes which have a higher rate of program participation, while the California and Massachusetts studies have focused on single family homes.[21]

The Arizona Public Service (APS) Residential New Construction Program, which also used Delphi panels in its evaluation, had a net-to-gross ratio of 1.39. A key difference between the APS program and programs in California and Massachusetts is that the former has a much higher participation rate—49% of all homes constructed in the metro Phoenix area in 2010—which results in lower spillover savings.[22]

Several findings from the Massachusetts net impacts study are particularly noteworthy.

---

[19] Tetra Tech and NMR Group, Inc., *Estimated Net-To-Gross (NTG) Factors for the Massachusetts Program Administrators (PAs) 2010 Residential New Construction Programs, Residential HEHE and Multi-Family Gas Programs, and Commercial and Industrial Gas Programs*, July 20, 2011. Some of the savings estimated for California were credited to a separate Codes and Standards program.

[20] KEMA, NMR Group, Itron, Inc., and the Cadmus Group, *Phase II Report Residential New Construction (Single-Family Home) Market Effects Study*, December 6, 2010

[21] Tetra Tech and NMR Group, Inc., *Estimated Net-To-Gross (NTG) Factors for the Massachusetts Program Administrators (PAs) 2010 Residential New Construction Programs, Residential HEHE and Multi-Family Gas Programs, and Commercial and Industrial Gas Programs*, July 20, 2011

[22] Keneipp, Marshall et al. "Getting MIF'ed: Accounting for Market Effects in Residential New Construction Programs", International Energy Program Evaluation Conference Proceedings, 2011

- While the Program has a moderate free-ridership rate, non-participant spillover is quite high. Non-program homes are responsible for 75% of net savings in terms of MMBtu, 68% of electric savings, and 71% of natural gas savings.
- The Delphi panelists noted that the program has had a particularly strong effect on air infiltration, duct leakage, lighting, insulation installation grades, and some heating system efficiencies.
- When assessing net savings using the fuel neutral metric of MMBtu, natural gas is the fuel with the most net savings, followed by propane and then electricity.
- Lighting is responsible for 61.5% of all electric net savings. Program lighting is responsible for 25.7% of all electric savings while non-program lighting is responsible for 35.8%. It should also be noted that lighting accounts for 80.4% of the electric savings in program homes, and 52.6% of the electric savings in non-program homes.

The sizable net-to-gross ratio found by this study would seem to be at odds with the relatively low attribution scores provided for the Program by the homebuilder survey described in Section 2. NMR believes the net impacts and net-to-gross ratio calculated through modeling of the Delphi panel estimated efficiency values is nevertheless more valid than the homebuilder survey responses would indicate. The reasoning here is that:

- Builders responding to the survey are more likely to be limited to their own experiences, whereas the Delphi panelists were chosen for their wide-ranging expertise and focus on the Massachusetts new construction market as a whole, and/or experience outside of Massachusetts. Further, panelists received builder survey results and so were able to take them into account.
- As noted in Section 2, the builders do have a tendency to attribute any changes in their practices to “code,” even when code requirements affecting a particular area have not changed.
- Many of the factors receiving higher attribution percentages than the Program for changes in building practices, such as the availability of HERS raters and the adoption of the stretch code are due, at least in part, to the Program.
- Close to one-half of participating builders said the Program has had some nonparticipant spillover. Moreover, most participating builders said they made some changes to their building practices in order to go through the Program and most who build homes outside the Program said that they use building designs, practices, equipment or measures in these homes as a result of their experiences with the Program.

The following recommendations emerge from the findings of this study:

- *Assess the net impacts of the Program’s multifamily component.* While it may be difficult to assess net impacts in the low-rise multifamily market without a baseline study, the high-rise market may be examined after its planned baseline is completed. Since this market has been addressed by different programs, both commercial and residential, over the past few years, it would be necessary to consider the actions of the different programs before trying to quantify net impacts.

- *Continue to conduct baseline studies of non-program homes.* Since most of the homes being built in Massachusetts do not participate in the Program, non-participant spillover is an important component of the Program's net impacts. With the expanding number of stretch code communities and the introduction of IECC 2012, it is important to maintain up-to-date information on non-program home characteristics.
- *Continue to emphasize practices such as quality insulation installation in trainings.* The comparison between program home and non-program home insulation installation grades illustrates the dramatic effect the Program has had on building practices, probably more than would be apparent when examining only the equipment and materials used.
- *Continue to carefully document any and all program actions that may affect the market.* Delphi panels may be used in future efforts to estimate program net impacts and it is important to provide a thorough record of the Program's involvement in training, marketing, code support, and other areas, particularly where nonparticipants are affected.